LUME 52 NUMBER 9 . . . ONE YEAR FOUR DOLLARS

GENERAL ELECTRIC Review

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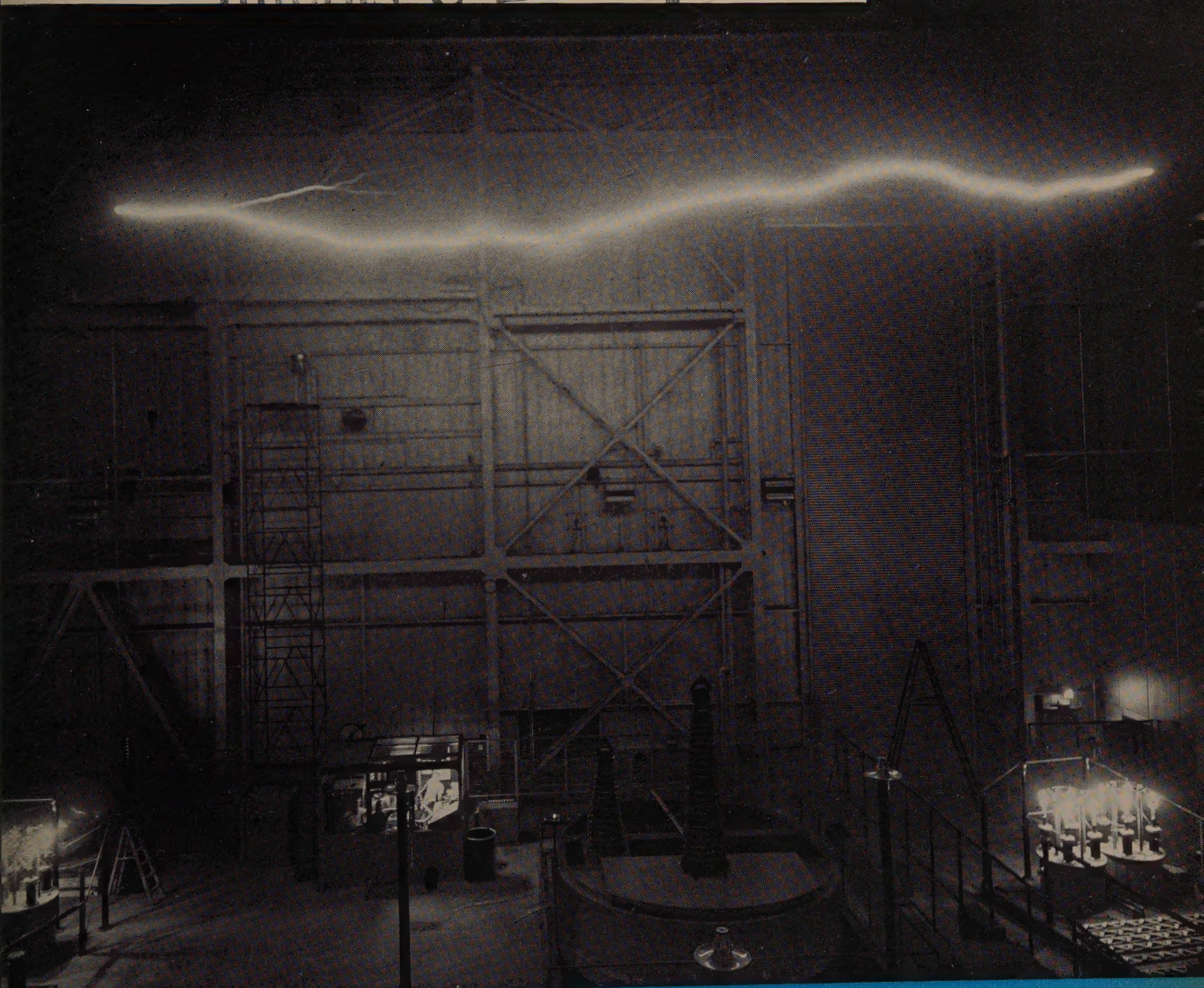

September, 1949

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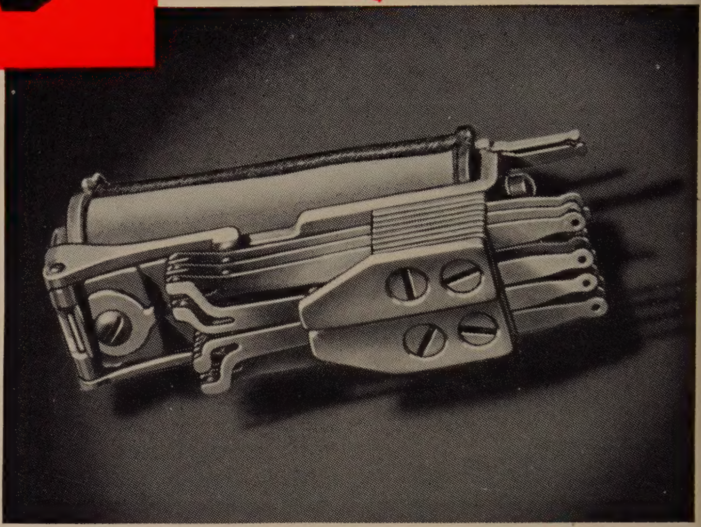

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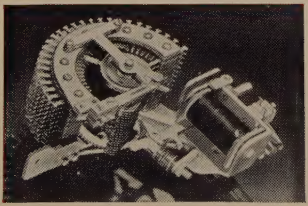

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SWITCHES

Digest

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Internal mechanism is designed for xtra reliability. High coercive Alnico agnet assures proper alignment, even nder severe operating conditions. Large ir gap reduces danger of stickiness aused by foreign particles. A variety of ypes and ratings in round or square ases are available for use in radio, teleision or testing equipment. Get comlete details from Bulletin GEC-368.

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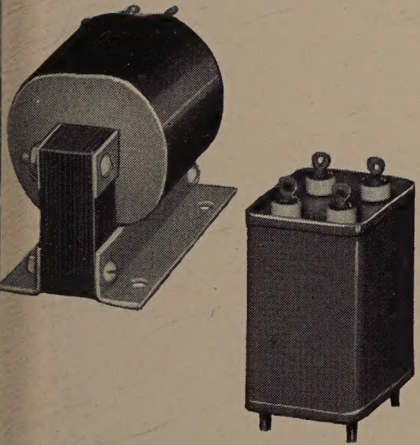

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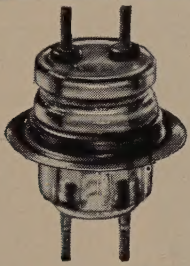

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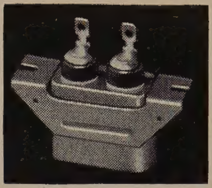

Case style CP 63 (shown above) is rated 0.1–0.1 muf and 1000 volts. Other ratings range from .01 muf to 15 muf and from 100 to 12,500 volts. Write for detailed description and operating data in bulletin GEA-4357A.
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CHARLES EDWARD WILSON

PRESIDENT OF GENERAL ELECTRIC COMPANY

On September 2, 1949, Mr. Wilson completed fifty years of General Electric service. This half century has seen the greatest achievements of industry, many of them accomplished through the developments and applications of electricity

GENERAL ELECTRIC Review

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HALF CENTURY OF THE UNCOMMON MAN

Some years ago, during World War II, a then well-known political figure foresaw a bright post-war world, a new era of peace and wealth. His view of the new standard of living in the new world was summed up in his definition of the war's objective: the war was being fought so that the "common man" everywhere in the world could enjoy a quart of milk every day. This, he added triumphantly, was to be the "Century of the Common Man."

Being the Friend of the Common Man, with capital letters, became for a number of years the chief mission of this political phrasemaker. Some home-spun philosopher once observed that the Lord must love the common people because he made so many of them. Whether or not this be true, it seems that political phrase-makers love Common Men because they assume so many of them are voters. Promising the Century of the Common Man comes pretty close to promising something for everybody, which has long been considered the ideal political platform.

The difficulty, as is often the case with political platforms, lies in carrying it out. In the first place, the meaning of the Common Man was never clearly defined. It was impossible to tell whether the objective of the Century of the Common Man was to raise everyone everywhere in the world to the level of the highest or to reduce all to the level of the lowest.

More than one hundred and fifty years ago the founders of our political system took a broader view of the "Common Man." They did not speak of the equal right of every man to a quart of milk a day, nor did they set any other arbitrary material standard. Rather they sought to establish equality on a basis which is an incentive to the progress of all men, common and otherwise. That is the equality of opportunity to improve himself and the world as he finds it with the talents he is given.

If all men were not only born equal but stayed that way, the Century of the Common Man, in which every man remained equal, common and average, would have arrived. But progress would have stopped. It is the equal opportunity to do a little better than the other fellow which has led to every improvement in civilization since the beginning of time. If Edison had been content to play the role of the "Common Man," there would have been no electric light, no phonograph, no one of the thousand other inventions by which he established himself as an Uncommon Man.

So it is in every walk of life. It would be a dull game in which every man had a common batting average. It's the Uncommon Man who bats in the runs that win the games. The important thing to remember is that when the Uncommon Man wins for himself, he wins for the whole team.

It is no paradox that two of the ideals dearest to Americans are equality and "uncommon-ness." Equality of opportunity boils down to a sense of fair play. "Uncommonness" is the ability to get ahead when the rules are fair.

It is no wonder that Americans are proud of a Charles E. Wilson whose career proves that both of these ideals can be lived up to. Fifty years ago Charlie Wilson started his career with nothing more than an equal opportunity to get ahead. Many might have called the opportunity less than equal for a boy leaving school to take a job at $3 a week. Surely it would have been easier at that stage to have been handed equality on some higher level by government decree.

But Charlie Wilson in 1899 had never heard of the Century of the Common Man. Reviewing the progress of the past fifty years, it seems fortunate that the pace has been set for the first half century by the Uncommon Man, by Charlie Wilson and many others like him. True it is that the goal of a quart of milk a day for everyone everywhere in the world has not yet been reached. But in America, where the pace is set by the Uncommon Man, we are coming closer to it every day.

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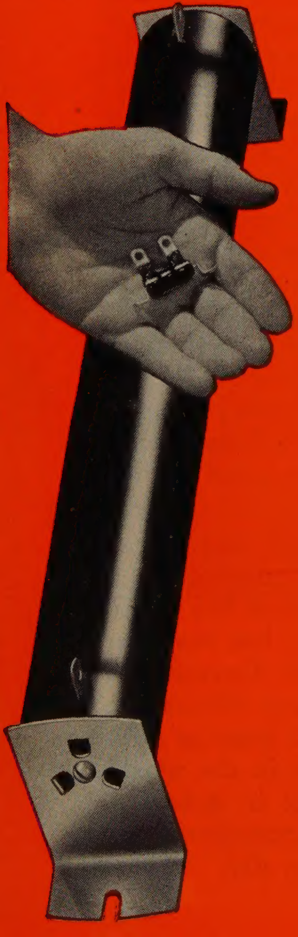

The extensive range of Ohmite types and sizes makes possible an almost endless variety of standard Ohmite resistors to meet each individual need. Ohmite offers resistors in more than 60 core sizes, in a wide range of wattage and resistance values. There are also 18 types of resistor terminals available. Included in the Ohmite line are fixed, adjustable, tapped, non-inductive, and precision units.

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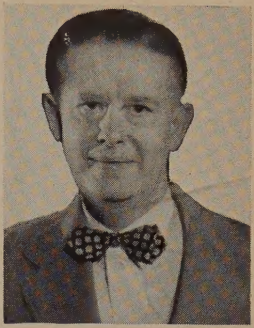
NEW HIGH-VOLTAGE ENGINEERING LABORATORY

The superior facilities provided in this two-million-dollar high-voltage laboratory will enable engineers to extend the research of high-voltage phenomena, thereby gaining new knowledge in the testing and developing and the operating of commercial high-voltage equipment of better quality at lower cost



By J. H. HAGENGUTH

High-voltage Engineering Laboratory
Pittsfield Works, General Electric Company

JHHagenguth

THE year 1949 marks another milestone for high-voltage research and development with the opening of the High Voltage Engineering Laboratory of the General Electric Company in Pittsfield (Mass.)

Entirely new and with greatly increased facilities, the High Voltage Laboratory will enable the Company's engineers to extend research and developmental work on high-voltage phenomena to previously unattained levels and at a greatly accelerated rate. That the importance of the new laboratory as a tool for cost reduction and product development may be more fully realized, it is fitting to review the principal accomplishments of the past.

HISTORICAL BACKGROUND

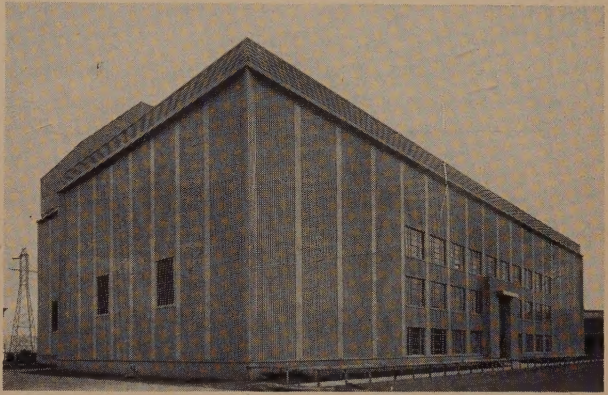
The first laboratory, constructed at Pittsfield in 1914, was the scene of many accomplishments. Early work, under the direction of F. W. Peek, Jr., was concerned primarily with alternating-current phenomena. The sphere gap was investigated and perfected as a measuring device for high voltages and the effects of frequency and air density on its accuracy were recognized. Limitations of the needle gap, particularly sparkover variation with humidity, were discovered.

Corona studies permitted formulation of laws of corona on transmission lines, which even today are considered as a solid basis for calculations.

Work on the effect of direct-current voltages on air, liquid, and solid insulation resulted in recommending direct-current voltage test on cables in the field as a quality-control test, a practice which is now used widely.

Suspension insulators of early manufacture could not be depended upon from mechanical and electrical considerations. Extensive work in the laboratory, including electrical, mechanical, porosity tests, determination of voltage distribution, and the shielding of strings contributed to a great extent to the perfection of suspension insulators as we know them today.

The investigation of natural lightning and its reproduction in the laboratory received a great boost from Dr. Steinmetz when his interest was aroused by lightning striking his camp on the Mohawk river in 1921. Peek was successful in increasing the voltages produced by artificial lightning or impulse generators by high-voltage alternating-current charging of the laboratory clouds or capacitors up to 3,500,000 volts. The development and use of the Marx circuit in 1927 removed limitations previously existing and opened up a new field of high-voltage research—that of reproducing at will surges similar to natural lightning.



Front view of the new High-voltage Engineering Laboratory, showing the Low Bay Building in the foreground. The High Bay is the tall building partially visible at the left rear, and behind it a tower of the laboratory transmission line

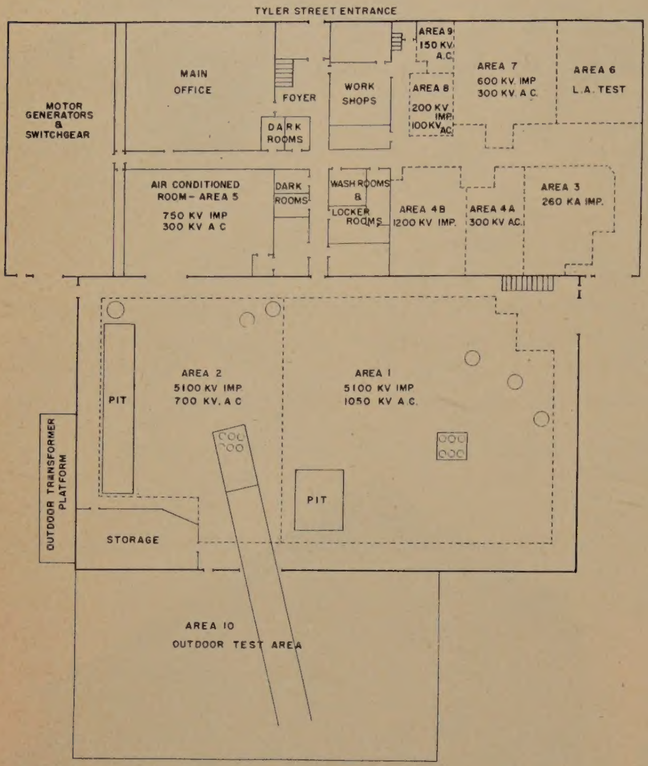
The introduction of Dufour's cathode-ray oscillograph by K. B. McEachron in 1925 in the Lightning Arrester Development Section at the Pittsfield Works gave high-voltage investigators the remaining tool needed to study natural lightning effectively and its effects on high-voltage apparatus in the laboratory.

A new terminology applying to the extremely fast phenomena under investigation was developed, such as "time-lag of sparkover and breakdown," "impulse ratio of sparkover and breakdown," and "microsecond" as the time unit appropriate to lightning and impulse work.

The new tools for reproducing natural lightning in the laboratory were used to determine the effectiveness of ground-wire protection of transmission lines, the effectiveness of lightning-rod protection of houses, barns, and other structures—such as oil reservoirs, oil tanks, and powder magazines. The results were incorporated into a code of lightning protection.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

Lightning investigations on transmission lines in the years 1927-1931 revealed the wave shapes of traveling waves on lines, but did not give sufficient evidence of the nature of the lightning stroke at its point of contact. In all these years, investigations of many groups resulted only in one oscillogram of a direct stroke to a line wire.


TYLER STREET ENTRANCE
MOTOR GENERATORS & SWITCHGEAR
MAIN OFFICE
FOYER
DARK ROOMS
WORK SHOPS
AREA 9 150 KV. A.C.
AREA 8 200 KV IMP. 100 KV AC
AREA 7 600 KV. IMP 300 KV. A C.
AREA 6 L.A. TEST
AIR CONDITIONED ROOM – AREA 5 750 KV IMP 300 KV A C
DARK ROOMS
WASH ROOMS & LOCKER ROOMS
AREA 4B 1200 KV IMP.
AREA 4A 300 KV AC.
AREA 3 260 KA IMP.
AREA 2 5100 KV IMP 700 KV. A C
PIT
AREA 1 5100 KV IMP 1050 KV A.C.
PIT
OUTDOOR TRANSFORMER PLATFORM
STORAGE
AREA 10 OUTDOOR TEST AREA

Floor plan of the first floor of the new laboratory

During this time, the effect of wave shape on impulse sparkover of rod gaps and insulator strings was investigated. A $\frac{1}{2}\times5$, 1×20, and a $1\frac{1}{2}\times40$ μs wave were recommended for standardization of testing procedures. Protective gaps for wood poles were studied. The co-ordination between line and station equipment was studied and recommendations included continuity of ground wires to and over the station and reduction of line insulation near stations.

The shielding of transformer windings was investigated and perfected. The first impulse test on a complete power transformer was made in 1930, inaugurating a period of extensive investigation of transformer-insulation impulse strength and the actual commercial impulse testing of transformers.

In 1934 the Laboratory came under the direction of K. B. McEachron. During the following years, he and his associates succeeded in obtaining a rather complete picture of lightning-stroke characteristics by installing automatic oscillographs in the tower of the Empire State Building, with its high incidence of lightning strokes, supplemented by photographs taken of the same strokes from nearby tall buildings. Concurrently, and for comparison, photographs were taken from a glass-enclosed observatory in Pittsfield. These investigations gave the first proof of the continuing character of the stroke current, confirmed the existence of mu tiple strokes, and resulted in considerable statistica material concerning lightning current wave shape, suc as front, rate of rise, tail, duration, and the charge conducted in a stroke.

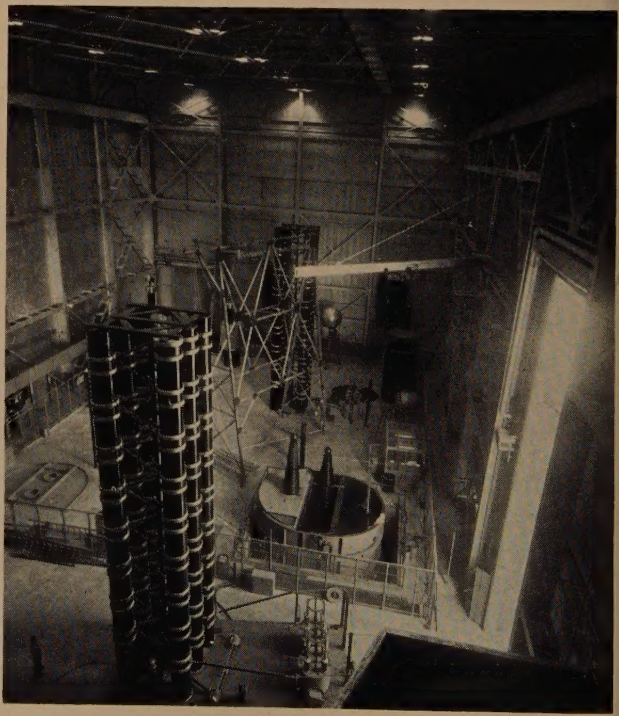
The destructive effects of lightning currents wer studied in the laboratory with the high-current gen erator developed in 1934. Evidence thus obtained fur nished valuable checks to oscillographic measurement on the Empire State Building.

Transformers and other high-voltage apparatus wer further investigated as to stress distribution and break down strength of the complete units and their com ponent parts. New methods of detecting failures wer developed, resulting in stricter requirements for desig and manufacturing methods. The extension of impuls testing to steep-front waves required the developmen of new measuring methods and disclosed certain law governing sparkover of air in the nonuniform field.

The emphasis of high-voltage research and develop ment during the Laboratory's existence thus shifte from alternating-current phenomena to work wit impulses, as the importance of lightning and othe surges on insulation practices became more clearl recognized.

THE NEW LABORATORY

The apparatus built in the Transformer and Allie Product Divisions of the Apparatus Department of th General Electric Company can be generally classified a high-voltage equipment. The variety in lines is great— comprising power, instrument, and distribution trans formers, bushings, fuses, capacitors, cable accessories lightning arresters, cutouts, and voltage regulators Likewise, the equipment ranges in rated voltage from

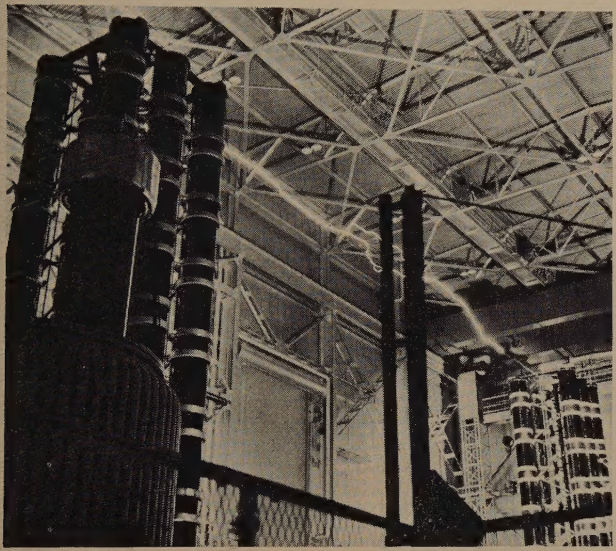


High Bay test areas. View from the crane platform, showing the two 5100-kv impulse generators. Large 50-ft roll door at right few hundred to several hundred thousand volts. The demand for developmental work from the various Line Divisions consequently is great. To satisfy this demand and to have sufficient facilities for basic studies of sparkover and breakdown phenomena, it was necessary to greatly enlarge the existing facilities.

THE BUILDING

The building is of steel-frame construction, with double steel walls insulated with a 1½-in. layer of glass wool. The wall panels are welded to the frame, thereby providing electrical shielding. The shielding is completed by a steel reinforcing grid which is in the concrete floor and welded to the building steel.

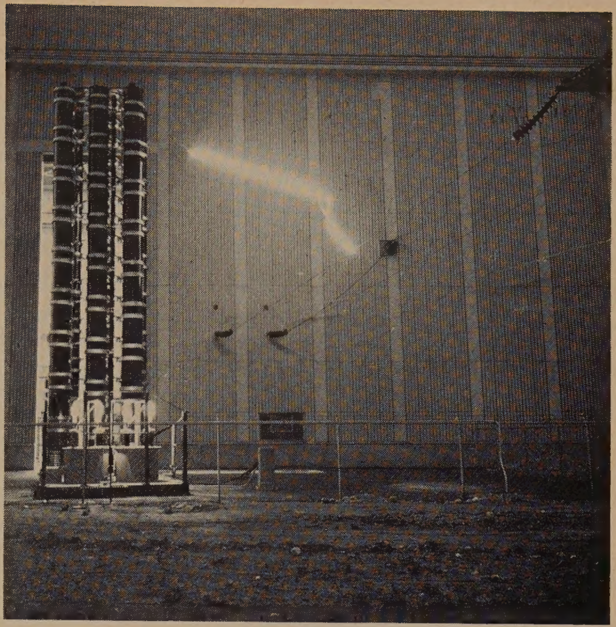
Two adjoining buildings—the High Bay and the Low Bay—provide a combined floor space of 51,000 sq ft., as shown in the accompanying laboratory floor plan. The High Bay is a single room having the dimensions given in Table I. Except for two observation windows, it has no windows in the outside walls. Their absence facilitates darkening the room for corona observations. The large clear space is required to obtain strike clearance for the extremely high alternating current and impulse voltages which can be developed by the testing equipment.



A 50-ft spark discharge between the two 5100-kv impulse generators. Another view is shown on the front cover

The Low Bay is divided into three parts: a large test hall about 84 ft square extending to the roof, a motor-generator room, and an air-conditioned room extending over two floors, and a three-floor office area. The entire third floor is used for lightning arrester development.

The air-conditioned room is insulated by means of multiple layers of sheet aluminum, with air space between layers. Floor construction consists of eight inches of concrete for a base, suitable insulating materials, sand fill, and a nine-inch top layer of concrete. Refrigerator-type doors are provided for access and large Thermopane windows serve for observation. The air-conditioning equipment is designed to provide a temperature range between 0 F and 100 F with a wide range of humidity control.



The portable 5100-kv impulse generator in the outdoor test area discharging a 25-ft spark to the laboratory line

The motor-generator room is separated from the remainder of the building by a double wall and three feet of air space to minimize the transfer of noise.

SERVICES

The electric-power supply is obtained from the 13.8-kv Works distribution system through Pyranol insulated transformers that have a total rated capacity of 4300 kva and that are installed outdoors. Lighting and utility power is distributed at 440 volts and stepped down to 115/230 volts by dry-type transformers at load centers.

Test power for alternating-current high-voltage tests is supplied by three generators: one 1000-kva generator and two 500-kva generators. Two 500-kw 500-volt direct-current generators are also available.

HEATING

Steam is supplied to the building at 125 lb per sq in. pressure and distributed at 25 lb pressure. To minimize air currents, radiant heat is used in the High Bay in the form of 12,000 linear feet of 1¼-in. wrought-iron pipes, 12 in. on center and buried in the concrete floor slab, 4¼-in. below the surface. The system provides 70 F within the building for an outside temperature of

TABLE I

DIMENSIONS OF THE NEW HIGH VOLTAGE ENGINEERING LABORATORY

	High Bay Building	Low Bay Building
Total length	165 ft	215 ft
Total width	95 ft	84 ft
Height	86 ft	55 ft
Height to roof truss	75 ft	44 ft
Total floor space	16,000 sq ft	35,000 sq ft

0 F. For stand-by purposes and extreme weather, conventional fin-type radiators and unit heaters are available.

The Low Bay is equipped with only fin-type radiators and unit heaters.

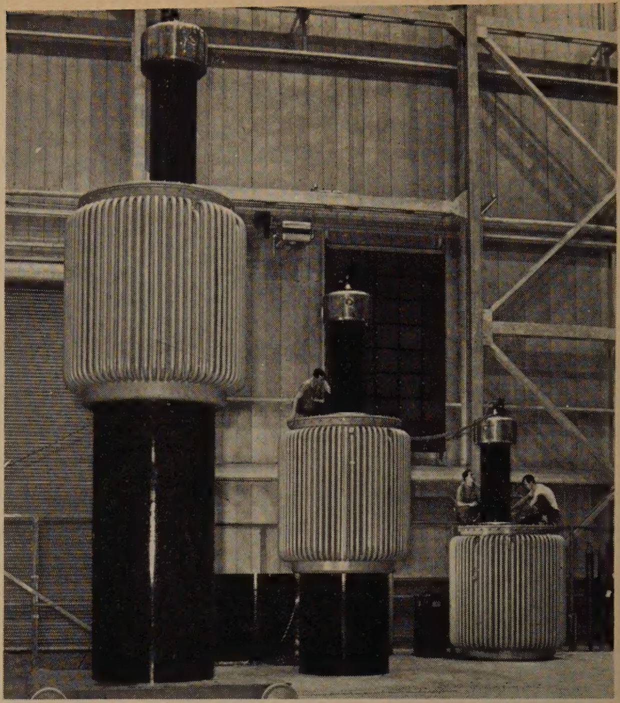
Filtered-air intakes and roof-exhaust ventilators are used in the large areas. Inside rooms are connected to a separate exhaust system.

CRANES

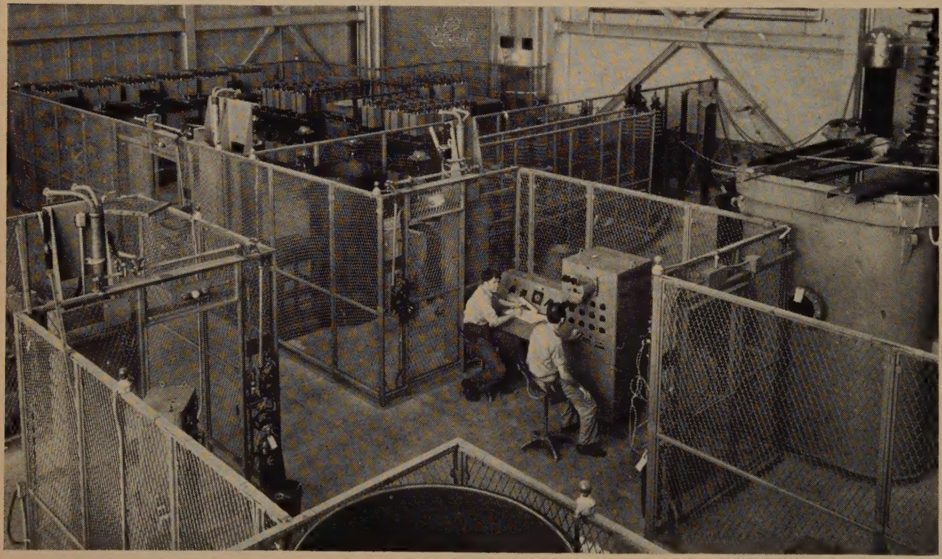
The High Bay is serviced by a 25-ton crane, with access by a small elevator because of the high elevation of 65 ft. A 10-ton crane is available in the Low Bay test area, and also services platforms on the second and third-floor levels. Several jib cranes and small floor-operated cranes service the High Bay, the air-conditioned room, and the mechanical workshop. Equipment too heavy to move by crane is brought in by drop-frame trailer and tested directly on the trailer.

TEST EQUIPMENT

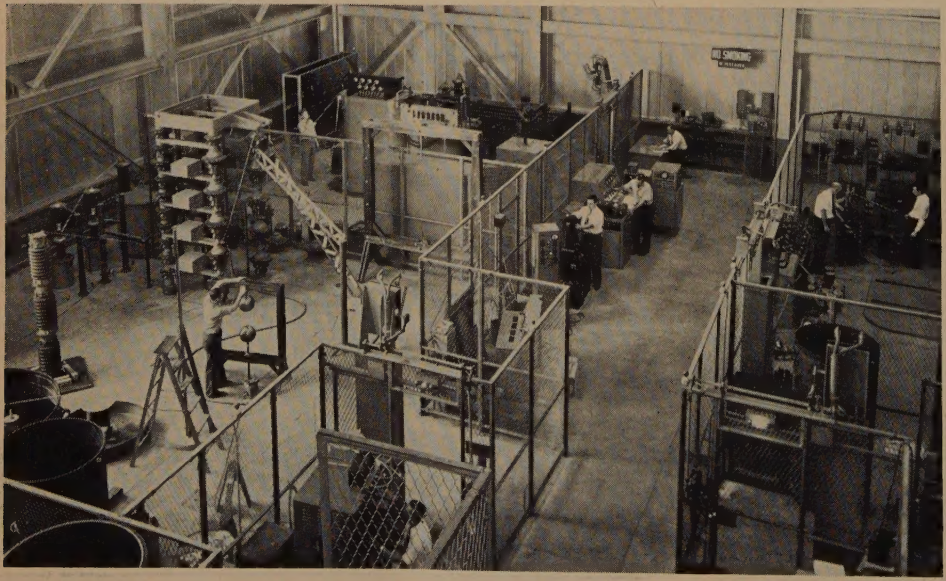
The primary purpose of the Laboratory is to conduct development and research work on apparatus used for



Three 350-kv 1000-kva testing transformers being connected in cascade



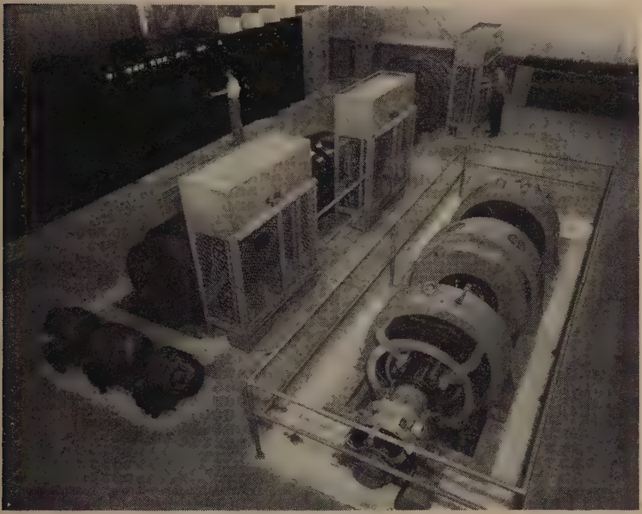
View of test areas in Low Bay. Right foreground shows a-c and impulse controls and cathode-ray oscillograph. The high-current surge generator, capable of delivering 260,000 amp peak current, is located in the background



Another view of test areas in Low Bay. A 600-kv impulse generator is shown in the large area at the left power transmission and distribution. This requires knowledge of the effects of normal-frequency voltages and of transient voltages produced principally by lightning.

The two essential types of equipment needed for investigation therefore are: (1) impulse generators, to study the effects of lightning under controlled conditions; and (2) alternating-current testing transformers, to study the effect of normal overvoltages.

In many cases it is necessary to study the effects of both these types of overvoltages. Therefore, six of the nine test areas are equipped with impulse generators and alternating-current testing transformers. The two large test areas in the High Bay contain one 5100-kv impulse generator each. These can produce a peak voltage of 7500 kv to ground at a current of 33,000 amp when operated individually, or 66,000 amp when connected in parallel. When the generators are charged to opposite polarities, a gap of 55 ft can be sparked over between them.



View in the motor-generator room

These generators are of the same type as used in Steinmetz Hall at the New York World's Fair, using tub-type capacitors each rated 100 kv, 0.33 microfarad. The height of the generators is 44 ft and a clearance to ground between 31 and 33 ft is needed to confine the discharge to a predetermined path. The charging voltage of the generators is 300 kv.

Three 350-kv 1000-kva testing transformers connected in cascade can deliver 1050 kv (rms) to ground in one area. Two similarly connected units permit tests up to 700 kv (rms) in the second area. By connecting all five units in cascade, it will be possible to sustain 1750 kv (rms) to ground. The other four smaller impulse generators range from 200 kv to 1200 kv, with alternating-current test voltages ranging between 100 kv and 300 kv. This permits a wide range of tests to be applied without rearranging the test equipment.

A surge-current generator is available capable of producing 260,000 amp at 50, 100, or 150 kv.

All surge measurements are made with hot-cathode type of cathode-ray oscillographs. Two of these are of special construction, containing two cathode-ray tubes for simultaneous recording of two transients. Thirty-five-millimeter cameras are used to photograph the screen of the tubes for permanent records.

For the study of gases under pressure or in vacuum, a large 200-psi pressure tank is available for testing samples up to the 115-kv voltage class.

Humidity control is available not only in the air-conditioned room but the entire High Bay is equipped to increase the moisture content of the air in the room.

To study the effect of rain on flashover of apparatus, water of specified resistance is supplied to all areas. The correct resistance of the water is obtained automatically through an electronically controlled mixing device.

In many cases it is important to know the distribution of stresses in apparatus. Several transient analyzers, which are miniature impulse generators, are available to measure voltage distribution in windings, transfer of voltages between windings, and for transient studies of networks.

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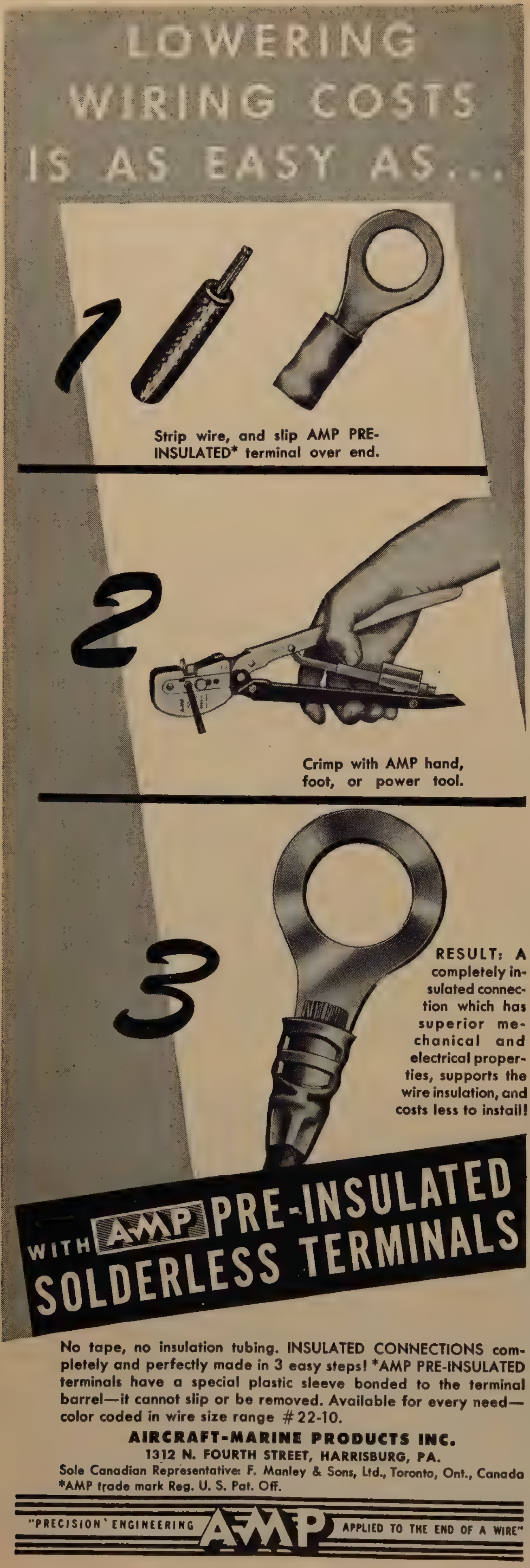
A 750-kv impulse generator and a 300-kv testing transformer in the air-conditioned room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(Continued from preceding page)

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GENERAL ELECTRIC REVIEW
SCHENECTADY, N. Y., U. S. A.

Who Doesn't Want Profits?

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Profits keep his plant going and his workers employed.

NOT THE WAGE EARNER

Profits keep his wages up and his standard of living high.

NOT THE INVESTOR

Profits are his inducement to risk his savings.

NOT OUR GOVERNMENT

Profits are a sizable source of state and federal taxes.

If not the factory owner, not the wage earner, not the investor and not the government — then who is against profits?

That can only be somebody who is opposed to private, free enterprise. Somebody who would like to see employment and wages at a riot-inciting low ebb. Somebody, in short, who can have only one purpose — to overthrow our democratic way of life.

This somebody has many faces. Sometimes he takes on the guise of a fellow worker. At other times he is a politician running for office. Often he takes on the appearance of the worker's friend. Whatever his disguise, he cannot fool you for long.

His script is a dead giveaway. As he denounces anything and everything American, he invariably sneaks in the suggestion that Communism is perfect.

SHERRON ELECTRONICS CO.

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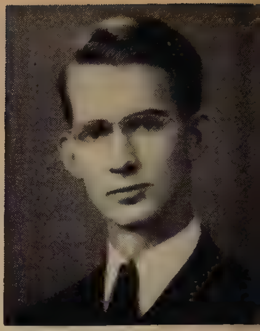
MANUFACTURERS OF ELECTRONIC DEVICES AND SHEET METAL FABRICATION

PERMANENT MAGNETS IN DRAG DEVICES AND TORQUE-TRANSMITTING COUPLINGS

How the characteristics of permanent magnets are utilized to advantage in those applications, some of which are relatively new. Calculation of the magnetic and force relationships



R. J Parke

By R. J. PARKER
Metallurgical Products Engineering, Chemical Department
General Electric Company

THE increased efficiency of permanent-magnet materials has made possible many useful applications in drag devices and torque transmitting couplings. In this article that describes the basic devices and compares their operating characteristics is included also a brief analysis of the magnetic circuit used in each type of device. Particular consideration is given to the efficient utilization of permanent-magnet materials.

Permanent magnets are used in four principal types of torque-transmitting devices:

(a). Eddy current
(b). Hysteresis
(c). Iron-oil magnetic couplings
(d). Salient-pole synchronous couplings.

The eddy-current and salient-pole synchronous couplings have been used extensively for many years. Later, applications of the hysteresis principle have become popular. Still more recently, the iron-oil magnetic-friction type of coupling has come to the attention of designers, and it appears that permanent magnets can be used to good advantage in this type of device where remote electrical control possibilities are not indispensable. In Fig. 1 is a graph showing the torque-slip characteristics resulting from the four basic types of couplings. It should be noted at this point that the synchronous-type coupling does not transmit torque under slip conditions.

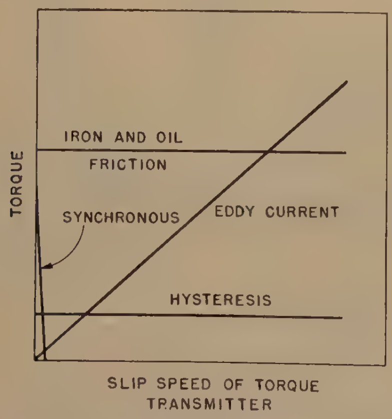


Fig. 1. Theoretical characteristics of basic torque-transmitting devices. (The synchronous type does not transmit torque under slip conditions)

EDDY-CURRENT DEVICE

Referring to Fig. 1, it will be seen that the eddy-current device has essentially a straight-line torque-speed characteristic, with the torque increasing linearly with the speed by virtue of the fact that the induced currents vary in magnitude with the speed of the rotating field. This basic characteristic is extremely useful in damping movements, since a restoring force proportional to the speed is obtained. Tachometers and speedometers, such as the one shown in Fig. 2, are popular applications of the eddy-current principle.

Fig. 3(a) shows a magnet pole and conducting medium with the paths of induced currents. Suppose the conducting plate is moved to the right; electromagnetic poles are induced due to current flowing as shown. These induced poles have such polarities that their reaction with the permanent magnet poles produces a retarding force. The torque developed is dependent upon the magnitude of the induced currents which, in turn, are dependent upon the voltage induced and the resistance of the path.

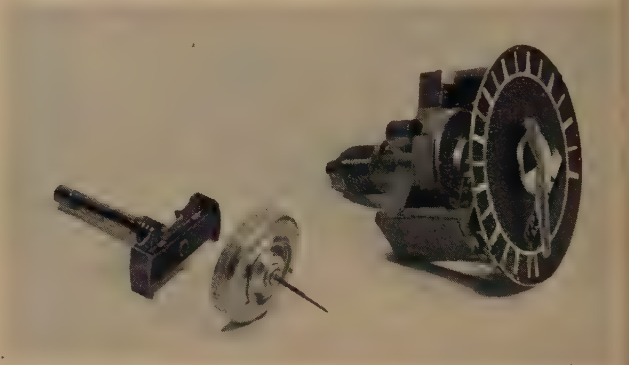


Fig. 2. The driving permanent magnet and the driven eddy-current cup of an automobile speedometer, together with the speedometer shown complete

The basic torque, in dyne-cm, is given by the formula:

$$T=\phi^2a^2X\,\omega/1000\,A\,\theta\,\rho$$

where ϕ = Total flux at magnet pole (lines)
X = Disk thickness (cm)
a = Length torque arm (cm)
ω = Angular velocity (rad./sec)
A = Area magnet pole
θ = Variable coefficient depending on completeness of eddy-current paths
ρ = Resistivity of disk (microhm-cm).

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—Editor

Inspection of the torque equation shows that T is proportional to ϕ^2X. Since ϕ^2 is dependent on the air gap, which is in turn determined by X when there is an ron return path for the flux, it appears that there must be some optimum relationship to govern the selection of X. Referring to FIG. 3(b), let G equal the total gap at one end of the magnet. Let M equal the air part.

Then $\quad G=M+X$

Since ϕ diminishes linearly as the gap length ncreases over a small range,

$$T \propto \phi^2X \text{ and } T \propto X/G^2$$

Then $\quad T \propto (G-M)/G^2 \propto (1/G)-(M/G^2)$

Differentiating T with respect to G

$$dT/dG=(1/G^2)+(2M/G^3)=0$$

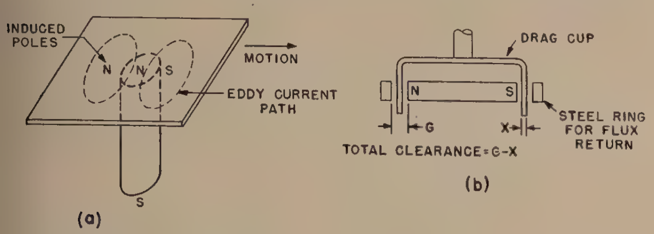


Fig. 3. Elementary diagram (a) showing how eddy currents are set up in a metallic material moving with respect to an adjacent magnet; and (b) some of the design considerations in practical application of that principle

Fig. 4. Hysteresis torque unit for control of tension in textile applications. Shown removed, and at the right, is the magnetic shunting device. The thread or yarn, not shown, passes part way around the periphery of the spoked-pulley element

or $\quad G=2M$ for maximum torque

Since $\quad G=M+X$

$$2M-M-X=0$$

$$M-X=0$$

$M=X$ for maximum torque

In the eddy-current design, the mechanical clearance M should be made the minimum necessary and the eddy-current material thickness should be made equal to M.

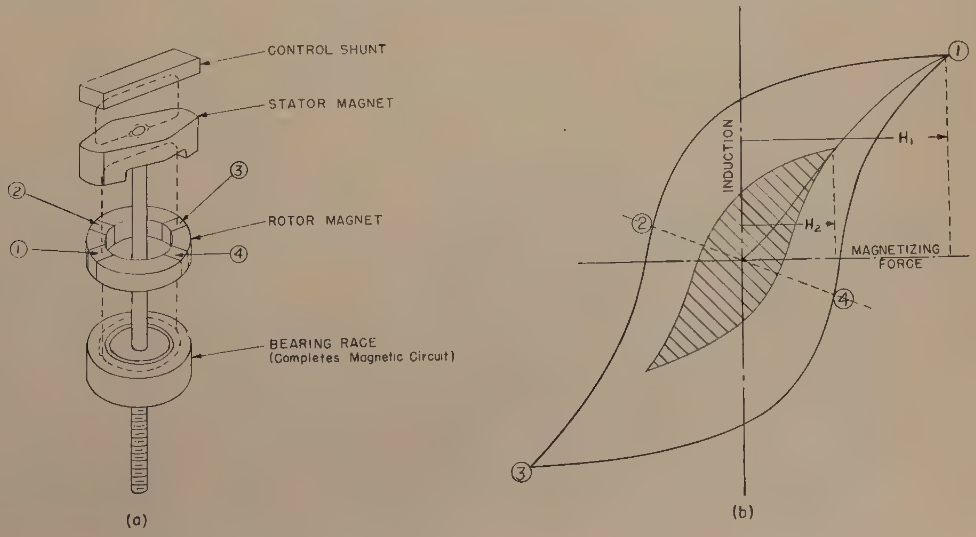
HYSTERESIS DEVICES

In hysteresis drag devices the constant-torque characteristic is obtained by virtue of the fact that the work done per revolution is constant and independent of time. The textile and wire industries are particularly interested in utilizing applications of this principle. In such applications, a thread or wire is passed over a pulley attached to one of these devices. The device then acts as a tension control and the thread or wire is held closely to the desired tension regardless of variations in the speed of the winding equipment.

A hysteresis device developed for the textile industries is shown in FIG. 4 with the flux-shunting cap separate. This device produces approximately 0.5 in.-oz torque. Basically such devices consist of a rotor of hysteresis material and a magnetizing stator magnet—and for an adjustable-torque device some means of control. To gain magnetic efficiency, a return path is also provided for the magnetic flux threading through the hysteresis ring. FIG. 5(a) shows an exploded-view drawing of the device and FIG. 5(b) the hysteresis curve of the rotor material.

To understand the operation of the hysteresis type of device, refer again to FIG. 5 and follow the magnetic experiences of a small element of the hysteresis ring as it is rotated through 360 deg. At position *1* in FIG. 5(a), the element is directly under one pole of the stator magnet, which condition corresponds to point *1* on the hysteresis curve. By turning the rotor 90 deg with respect to the stator bar magnet, the magnetic induction drops to point *2* on the curve. Due to the heavy self-demagnetizing effect on the ring itself (induced

ig. 5. Diagram (a) illustrates the lements of a practical form of ysteresis drag device. (For clarity he elements are shown separated.) n (b) is shown the hysteresis cycle f the rotor magnet



poles very close together), the element remains at this low value of induction until it goes under the other pole of the stator magnet, at point *3*. The next 180 deg of rotation carry the element through the symmetrical third and fourth quadrants of the hysteresis loop. The loop area represents energy loss due to work done on the magnetic material, which manifests itself as heat radiating from the ring. The energy has been supplied by mechanical input.

The expression for hysteresis torque will now be developed and it will show that the torque is independent of speed.

Each particle of the ring-shaped rotor magnet will be carried through a complete hysteresis cycle by each pair of poles P on the stator. Energy equal to the area of the hysteresis loop of the rotor material will be released in the form of heat. This is work done on the internal structure of the ring material. Each part of the ring is subjected to the same loss. For a given volume V of ring in cm³, and for a material having energy loss E_h in joules/cm³/cycle equal to $\frac{1}{4\pi 10^8}\int HdB$, the energy loss per revolution will be E_hVP joules. When the ring is turning at N revolutions/minute, the total energy loss will be E_hVPN joules/minute.

Since 1.356 joules = 1 ft-lb, and 33,000 ft-lb/min. = 1 HP

$$HP = E_hVPN/(1.356 \times 33{,}000)$$
$$= 2.24\ E_hVPN \times 10^{-5}$$
$$HP = 2\pi TN/33{,}000$$

(in which T = Torque in ft-lb).

Equating these two expressions for horsepower,

$$2\pi TN/33{,}000 = 2.24\ E_hVPN \times 10^{-5}$$

Solving for torque,

$$T = 11.75\ E_hVP \times 10^{-2}\ \text{ft-lb}.$$

In Fig. 6 is shown the value of rotor loss plotted against magnetizing force for various commercially available permanent-magnet materials. The superiority of alnico 5 and 6 is shown. For economical use of magnetizing force it appears desirable to operate alnico 5 at approximately 0.20 joules/cm³/cycle. In conjunction with selecting the proper value of magnetizing force, another important consideration in a practical circuit must be given attention. In Fig. 7(a) are shown an alnico 5 stator magnet and an element from a hysteresis ring. Initially the magnetizing force of the gap (H_g) before inserting the ring element is found to be 3800 oersteds. Upon inserting the ring element the magnetizing force drops to a very much lower value (H_e in Fig. 7(b)), approximately 600 oersteds. This drop is due to the free-pole demagnetizing effect of the ring-magnet element (H_s) which is present because of the reluctance of small series gaps, and also due to the high-reluctance path afforded by the alnico 5 stator magnet.

For those reasons, shown graphically in Fig. 7(b), in practical designs magnetizing forces of 6 to 8 times the net effective magnetizing force required (H_e) must be obtainable from the stator assembly. The net effective magnetizing force is the value arrived at by consulting the curves in Fig. 6. The demagnetizing effect, or the slope of the effective air-gap line in Fig. 7(b), can be estimated by careful analysis of the magnetic circuit or by magnetic measurements on a model of the device. The value of H_g can be found graphically by laying off a line parallel to the air-gap line through the point on the hysteresis curve where it is desired to work.

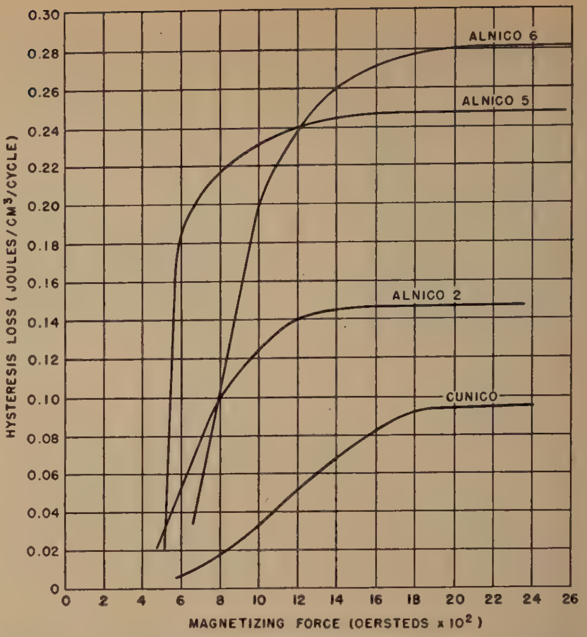


Fig. 6. Hysteresis-loss vs. magnetizing-force curves of various permanent-magnet materials. The superiority of alnico 5 and 6 for drag and torque-transmitting devices is indicated

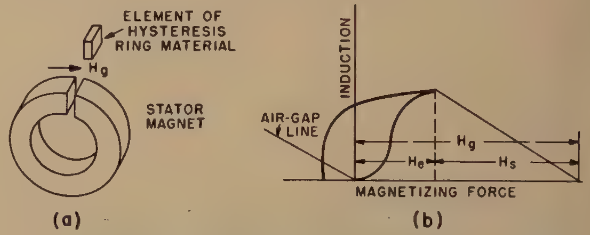


Fig. 7. Sketch (a) represents the stator magnet of a hysteresis device and an element of the hysteresis ring. Diagram (b) shows the corresponding magnetizing force and induction relationships

In the hysteresis device one has a choice of varying the stator air-gap or of shunting flux from the hysteresis ring to control the magnitude of torque. Fig. 5 illustrates the latter method of control, in which rotating the control shunt from zero to 90 deg with respect to the bar stator magnet forces the effective H in the air-gap from H_2 to H_1. Approximately 50 percent change in torque results.

Fig. 8 shows a 100-in.-oz hysteresis device originally developed for the wire industries. Here, another method of adjustment was employed. The bar magnets at the sides of the ring, when placed together with additive polarities, form the magnetizing circuit and produce a given magnetizing force in the ring material. Now if one bar is rotated slightly with respect to the other, the air gap is effectively increased and the magnetizing force is at an angle with respect to the axis of the hysteresis ring. The latter effect contributes to the adjustment, since the alnico 5 ring material develops its maximum hysteresis loss when magnetized in the direction parallel to its axis, because the ring was heat treated in a magnetizing field parallel to its axis. Using this method of adjustment, 90 deg rotation of one bar with respect to the other gives approximately a 2 to 1 variation in torque.

Referring back to the basic equation for torque, it is possible to use many pairs of poles and greatly increase the output. However, multiple-stator structures tend to be less efficient in the higher-energy, directional, permanent-magnet alloys. It is necessary to preserve a minimum length to pole-area ratio if the density level of the stator is to be at an efficient value. Multiple-pole structures tend to become expensive to manufacture because of the more elaborate heat treating and magnetizing equipment. However, in space-limited designs they can often be used to advantage.

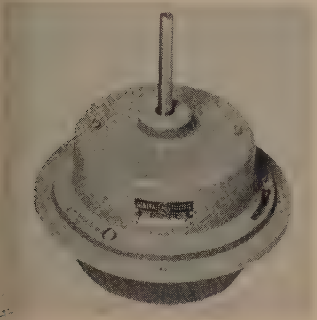
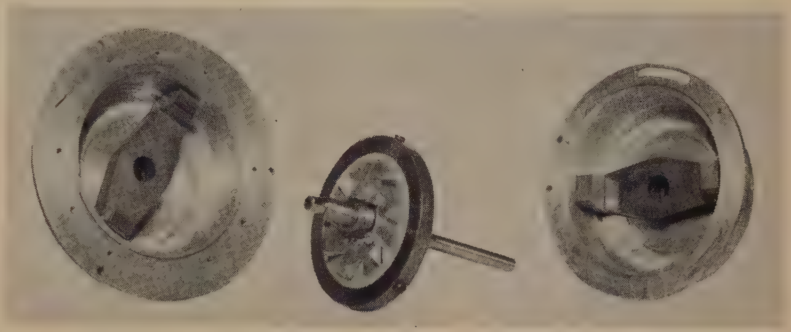


Fig. 8. At the left, a 100-in.-oz hysteresis drag device as developed for controlling tension; and at the right, the components of the device



IRON-OIL MAGNETIC COUPLINGS

The recent popularity of the iron-oil magnetic-friction coupling has opened up a new field for permanent magnets. Most of the published descriptions of this type of device have shown an electromagnet as a means of supplying and varying the flux density through the gap. However, a permanent magnet can be used to good advantage in many applications, particularly those where the coupling is called upon to slip at a given torque value and the control feature offered by an electromagnet is not required. For devices of this nature, it is obvious that a permanent magnet has many inherent advantages over an electromagnet. Such a device is shown in Fig. 9, where the pinion is a magnetic return path for the flux emanating from a two-pole alnico rotor. In this device, axial slots in the inner surface hold a reservoir of iron-and-oil mix which is uniformly wiped into the small air-gap as the device slips.

Even in applications where torque adjustment is a necessity, permanent magnets may be employed by using an adjustable shunt or by so moving the air-gap that the flux density in the working air-gap is changed.

The present problems in applying these iron-oil devices are sealing the mixture and protecting the bearings. Conventional bearing seals are not completely effective against the fine iron powder used. Magnetic traps, which take the form of a permanent magnet with pole pieces directly adjacent to the bearing, have been used with some success in preventing the migration of iron particles along the shaft and into the bearing. Another important problem to be considered in applying this type of coupling is the one of temperature rise in the device. This problem is accentuated by the high effectiveness of these devices which makes it possible for units of extremely small size to handle several horsepower. For this reason the iron-oil device is not at present suitable as a drag device—that is, for applications where it is necessary that the rotor slip continuously. However, these devices can be used in applications where the slip is intermittent and of short duration.

From the magnetic device design point of view, iron-oil fluid couplings are relatively simple and it has been found for all practical purposes that the torque developed is directly proportional to the magnetic-flux density in the working gap and to the effective area of the gap through which the flux passes. Since this is fundamentally a friction device, the magnetic-flux density controls the coefficient of friction between the working surfaces. As a rule of thumb, approximately 10 pounds of force can be developed per square inch if the flux density is 50,000 lines per square inch. The torque-speed characteristic under slip conditions is essentially constant.

SALIENT-POLE SYNCHRONOUS COUPLINGS

Salient-pole synchronous couplings, such as are commonly used in flowmeters, pumps, and in general wherever it is desired to transmit motion to a sealed unit, have been successfully used for many years.

Such an application is shown in Fig. 10. In this type of synchronous drive a displacement between the driven member and the output member is necessary for torque to be developed. If the torque capacity of the coupling is exceeded, one member will slip with respect to the other and the torque will drop to zero as was indicated in Fig. 1. The output member will not again pick up until the driven member is stopped or reduced to a very low speed.

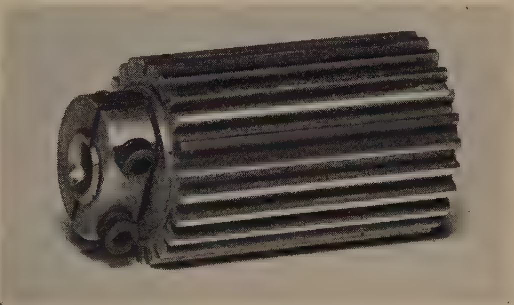


Fig. 9. A pinion that contains a permanent-magnet iron-oil coupling device and acts as the return path of the magnetism

To understand the fundamental principles involved, consider the energy relationships between the bar magnet and the follower in FIG. 11(a). First note that the steel follower is displaced 25 deg with respect to the magnet, and that the bar magnet has been fully magnetized and is operating at point A on its demagnetization characteristic, shown in FIG. 11(b).

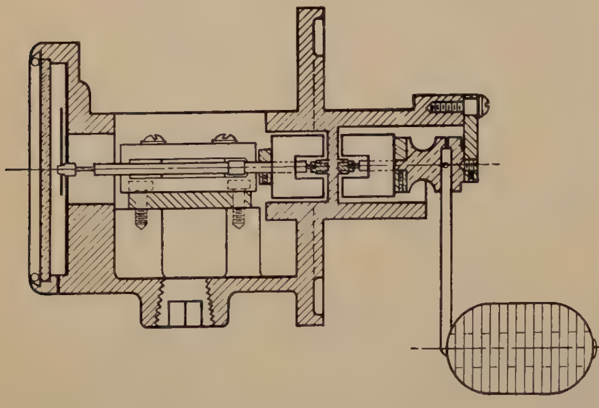


Fig. 10. Cross-section of a salient-pole synchronous-type coupling, utilizing permanent magnets. Synchronous couplings are applicable to drives where slipping is not required

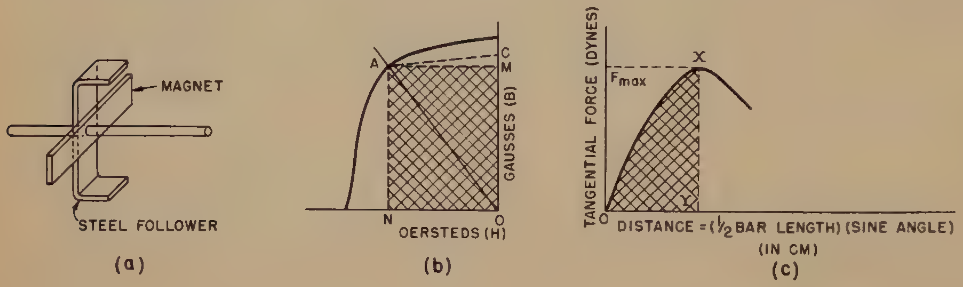


Fig. 11. Elementary diagrams (a) of salient-pole synchronous coupling; (b) magnetization characteristics of the coupling; and (c) force-distance characteristic

The rectangular area $AMON$ is proportional to the external-field energy produced by the bar magnet. Line OA is determined by the geometry of the bar, and in the interests of efficiency this geometry should be so chosen that the rectangle will have maximum area. This insures having maximum field energy available with minimum magnet volume.

If the steel follower member is now allowed to align itself with the magnet, the free-pole demagnetizing influence will be removed and the operating state of the bar magnet will shift along to point C, FIG. 11(b). The external magnetic-field energy is thus converted into mechanical work, and a tangential force acting between follower and magnet is present whenever one attempts to displace the follower from the axis of the magnet.

The area $ACON$ represents the magnetic-field energy released for doing mechanical work for each cubic centimeter of permanent-magnet material, and this field energy in gauss-oersted units can be converted into mechanical-unit dyne-centimeters or ergs by multiplying by 8π, the conversion constant. With the geometry represented in FIG. 11, maximum torque is developed at a displacement of about 25 deg. A typical force-displacement curve is shown in FIG. 11(c). The area under this curve represents mechanical work done. To determine the maximum torque developed by such a system, first find the change in total field energy by multiplying the area $ACON$ in gauss-oersted units by the volume in cubic centimeters, and dividing by 8π. Knowing that the maximum torque will occur at approximately 25 deg, and assuming that all magnetic-field energy relinquished has been transformed into useful mechanical work, as represented by area OXY, one can solve for the maximum tangential force by the following fundamental equations. (Only a small error will result from assuming OXY to be triangular for bar magnets.)

$$\text{Area } ACON \text{ (in gauss-oersteds)} \times \text{Volume (in cm}^3\text{)}/8\pi$$
$$= \text{Area } OXY$$
$$= F_{max} \text{ (in dynes)} \times D_{oy} \text{ (in cm)}/2$$

where $D_{oy} = \frac{1}{2}$ length bar × sin 25°

$$F_{max} \text{ (in dynes)} = 2 \times \text{Area } OXY \text{ (in ergs)}/D_{oy} \text{ (in cm)}.$$

While this method is based on several assumptions* it has the merits of providing an approximate solution to a different field problem and of showing the fundamental energy transformations involved.

FIG. 12 shows a torque-measuring stand and several permanent magnets suitable for torque transmission.

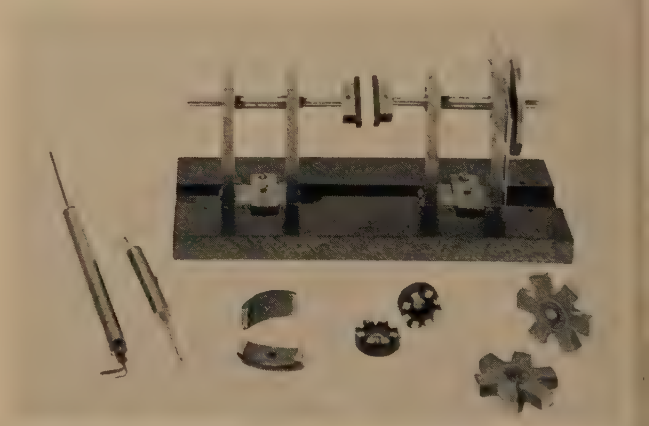


Fig. 12. Torque-measuring stand and auxiliaries used in developing and testing drag and torque-transmitting devices, together with some of the forms of permanent magnets employed in those devices

Multiple-pole couplings and couplings involving magnets for both driver and follower unit are used extensively.

In selecting a coupling device for a given application, such factors as period of slip, range of adjustment, and torque characteristics desired will influence the selection of a particular device.

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*One of the more basic assumptions is that the magnet is in a stabilized condition, which makes possible the equating of mechanical energy to external field energy without being concerned with energy loss due to changing internal structure of the magnet.

ENGINE-DRIVEN GENERATORS

D. W. Clugston

The application and design of generators to be driven by internal-combustion engines. Features of generator construction, selection of generator, standardization, types of mounting, torsional vibration, and parallel operation

By D. W. CLUGSTON

Large Motor and Generator Engineering Division
Fort Wayne Works, General Electric Company

ALTERNATING-CURRENT power for many applications today is obtained by the use of engine (diesel, gas, or gasoline) generator sets. Modern living and modern industrial methods are demanding more and more sources of electric power. The development and application of the diesel engine as a prime mover has been very rapid over the past few decades because of its high efficiency and low-cost operation. These factors, coupled with the relatively low initial cost, have resulted in an ever-increasing demand for engine-generator sets.

STATIONARY OR PORTABLE SETS

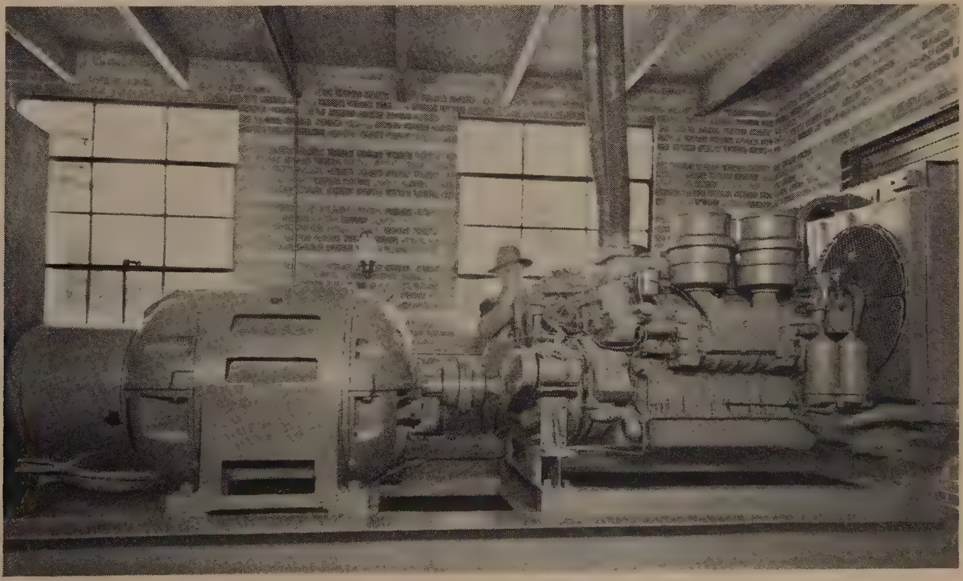
Depending upon their applications, engine-generator sets are designed for stationary or for portable use. Large and medium-sized sets for permanent installations may be classified as "stationary" and are usually emplaced on concrete foundations. Small and some medium-sized sets are generally "portable" in that both the engine and the generator are mounted on a common steel base or skid.

APPLICATIONS

Listed here are some of the applications of engine-generator sets. Although their purpose in most cases is to furnish a standby or emergency source of power, very often they are required for primary, or continuous service:

- Airports
- Construction Projects
- Factories
- Farms
- Filling Stations
- Flood-control Stations
- Food-canning Plants
- Golf Courses
- Hatcheries
- Hospitals
- Hotels
- Ice Plants
- Laundries
- Lumber Camps
- Marine
- Mining Operations
- Municipal Power
- Nurseries
- Office Buildings
- Oil Wells
- Quarries
- Radio Stations
- Railways
- REA Projects
- Refineries
- Refrigeration Plants
- River Locks
- Schools
- Shipyards
- Telephone Exchanges

From this list it can be seen that a relatively small portable set may be used by a hospital, telephone exchange, or farm for standby or emergency use, and a large stationary set by a municipality or REA project as a primary source of power. Furthermore, in isolated locations such as lumber camps or flood-control pumping stations, a small or medium-sized portable set may be required.



Skid-mounted 400-kw engine-generator set with two-bearing generator and flexible coupling

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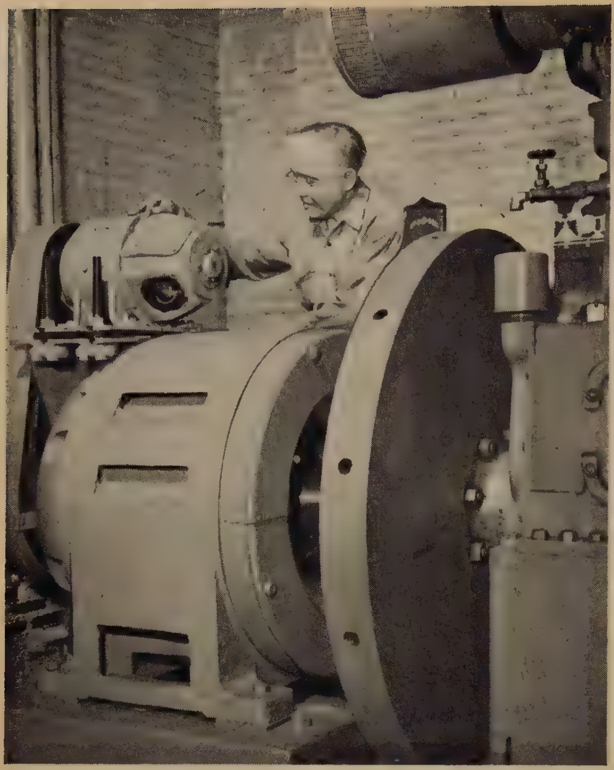
This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR



Stationary 200-kw engine-generator set emplaced on a concrete foundation, with single-bearing generator and rigid coupling

STANDARDIZATION

Engine-driven generator sets are for the most part sold by the engine manufacturer or by a specialized set builder. In either instance the engine or set builder obtains his generator from a manufacturer who specializes in the construction of rotating electric machinery. For any one engine there is a multiplicity of sizes and shapes of generators which may be required, because of the many variables affecting the generator, such as voltage, speed, number of phases, power factor, method of cooling, mechanical adaptation. Thus the initial application of any generator to an engine requires exacting co-ordination of design between the generator manufacturer and the engine builder in regard to mounting and assembling dimensions and coupling.

As yet there is no standardization of mounting and assembly dimensions for engines among the engine builders themselves; neither have the generator manufacturers established standardized outline dimensions for a-c engine-driven generators. This has often resulted in the manufacture of individual generators to suit the design requirements of the engine builder, which has, in turn, resulted in the production of many unrelated designs for the engine trade. In the past, the lack of any published standard engine-driven generator lines by generator manufacturers has accentuated the natural desire of each engine builder to ask for the production of generators that are so designed as to require the least number of changes to suit his standard line of engines. This procedure has resulted in expensive construction, in extra effort and time required in the factory, in longer shipment, and in some disruption of the factory load of standard generators being produced for other customers. Furthermore, there have been cases in which engine builders have demanded special constructions reducing generator ventilation to such an extent that the generator design was restricted. A standardized line of engine-driven generators is desirable for the following reasons:

(a). To uphold the quality of the product.
(b). To provide the customer with the benefits of lower cost and shorter shipment.
(c). To be able to supply an increasing quantity as demanded by the market.
(d). To have pertinent data available in the hands of the sales organizations.
(e). To accomplish the maximum consistency in the product manufactured.

Most of the principal generator manufacturers have published lines of engine generators. These lines have been established with sufficient design flexibility to permit incorporation of the usual modifications required by engine builders. More standardization of generators, even industry-wide, in regard to such factors as mounting dimensions, assembly dimensions, and coupling details will no doubt prove beneficial from an economic standpoint to the ultimate customer. However, the adoption of standard lines by individual manufacturers will go a long way toward bringing about lower costs, shorter shipments, and higher quality.

GENERATOR SELECTION

When applying a generator to his set the engine builder is interested in obtaining a high-quality product at the lowest possible cost and the shortest shipment. These are the main economic factors upon which his reputation and share of available business depend. There are also many generator features and other factors which affect his selection of a generator.

Application Information

First, he must have available adequate application information in the form of drawings, description, and construction or design details. From these aids and the advice of the generator manufacturer he can prepare his proposition quotations. For the orders he receives he must have final generator drawings from which to complete the details of the application.

Appearance and Quality

Appearance of the generator is of prime importance, since functional design involving smooth styling, or streamlining, is a definite trend in industrial machinery today. To insure ease of assembling the generator to the set, the engine builder wants a generator that has accurately machined dimensions, especially those which control the mounting and coupling alignment. Sturdy construction, with thick solid castings or strong, well-welded steel fabrications, is important because the generator must be able to withstand a reasonable amount of abuse and mishandling. The quality of the set must not be hampered by inadequate insulation or loosely braced generator windings.

Accessibility

That his ultimate customer will be satisfied, the engine builder desires a generator with adequate accessibility to those parts requiring maintenance and with such features as convenient electrical connections, flexible leads, and large roomy conduit boxes.

Modifications

More and more it is found that engine builders appreciate the cost and delivery advantages of confining their orders to standard-engine-line generators; but there are still a considerable number who require modifications such as short foot heights, special mounting dimensions, special adaptors for engine-flywheel housings, special drilling and dimensions for forged-on half couplings, extra-long leads, and special supports on the generator for engine parts. Such modifications, especially on an initial order, consume the all-important factor "time," and often result in a longer delivery promise. No doubt these modifications are dictated either by ultimate customer requirements or by exigencies of the particular engine design; as such, they must be recognized, and generator design must be adaptable.

Rotor Construction

When a generator is driven by an engine it is subjected to the high angular accelerations produced by the torque pulsations from the engine. These torque pulsations demand that the generator-rotor construction be extremely sturdy—more so than would be required for the application of a generator to a turbine, motor, or waterwheel. Therefore the generator rotors must have high-strength steel shafts, strong fans, and well-braced windings. When poles or spiders are built up with steel laminations they must be securely riveted together; poles must be securely attached to spiders (bolted or dovetailed); and spiders must be securely attached to the shafts (keyed and/or shrunk on).

Design Flexibility

It is not enough to build a sturdy rotor and say that it will be suitable for application to an engine-generator set. The natural frequency of the rotating elements must not be too close to any forced frequency produced by the engine; otherwise harmful torsional vibration will occur and cause eventual failure of the shaft or some other rotating part. Therefore, in order that a generator can be made to suit an engine application, its design should be made as flexible as possible in regard to the available shaft diameters and lengths; for by varying these dimensions the generator manufacturer can usually arrive at the dimensions which will be torsionally satisfactory.

MOUNTING

Direct connection is made either by means of (1) bell-housing mounting (the generator frame and engine frame bolted together to form a structural member) or by (2) surveyor's mounting (the engine and generator frames connected only through the base or foundation).

Bell-housing Method (Figs. 1 and 2)

With the bell-housing method of mounting, the generator can be either single-bearing or two-bearing. Generally the coupling is rigid torsionally but must provide for some angular misalignment. In the case of a two-bearing generator, additional provision should be made for offset misalignment. The apparent mechanical advantages of the bell-housing method of mounting are threefold. First, no alignment is required—just straightforward assembly. Second, the engine-generator set can be supported at its mass axis—"floating power." Third, the shortest over-all set length can be obtained.

During the war many applications of generators to engines made use of the bell-housing method of mount-

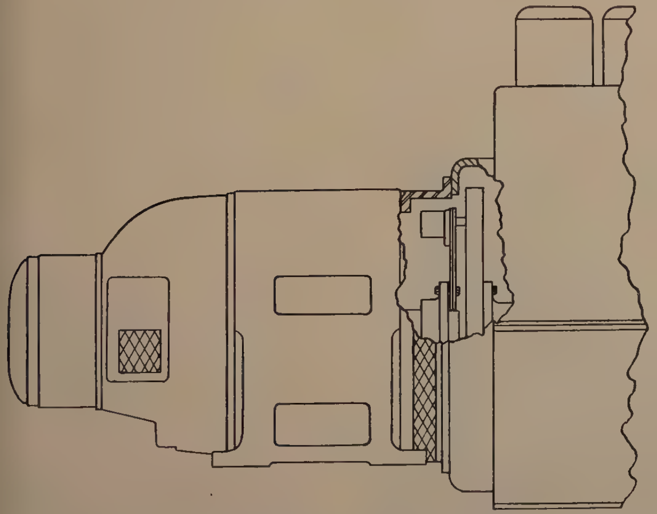


Fig. 1. Bell-housing mounting with single-bearing generator and direct-connected exciter. The flexible-disk-type coupling is rigid torsionally but provides for angular misalignment

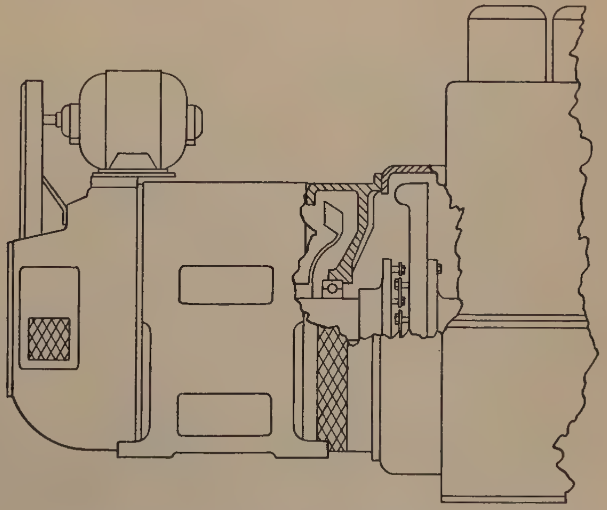


Fig. 2. Bell-housing mounting with two-bearing generator and a top-mounted belt-driven exciter. The coupling is flexible torsionally and also provides for both angular and offset misalignment

ing, thus realizing these advantages. Undoubtedly the fact that large numbers of identical machines were built at that time encouraged the use of the bell-housing method. However, this method is inflexible in that to apply generators of different ratings—consequently different frame sizes—to the same engine set, complete redesign of the set is often required. This in turn involves painstaking design co-ordination between engine builder and generator manufacturer, which tends to increase cost and lengthen shipment of the generator, so that today the bell-housing mounting is generally used only by those engine builders who have pre-established and engineered standard engine-generator sets with various but definite output ratings.

Surveyor's Method (Figs. 3, 4, and 5)

For the surveyor's method of mounting, the generator can also be single-bearing or two-bearing. Either of two types of couplings may be used with a single-bearing generator. The first is a rigid coupling (both torsionally and angularly), requiring very careful alignment of generator and engine. The other type is a coupling which, while rigid torsionally, does provide flexibility for both angular and offset misalignment. It thus eliminates the difficult alignment task, because a small angular misalignment will not produce shaft deflection. A two-bearing generator, when used with the surveyor's method, usually involves a coupling that provides for some angular and offset misalignment but at the same time is rigid torsionally.

At the present time most engine-generator sets in the 5-to-75-kw range make use of a single-bearing generator with a self-supporting flexible-disk type of coupling and surveyor's method of mounting. Occasionally a two-bearing generator with a flexible coupling and surveyor's method of mounting is used.

While some two-bearing generators are built in the range from 75 to 800 kw, by far the most popular application today involves the use of a single-bearing generator with forged-on half coupling integral with the shaft. This rigid type of coupling is used with the surveyor's method of mounting and requires very careful alignment. Apparently this style is used because of the simplicity of the coupling arrangement. Application of a flexible type of coupling to the larger-sized generators introduces considerable coupling design problems and additional expense.

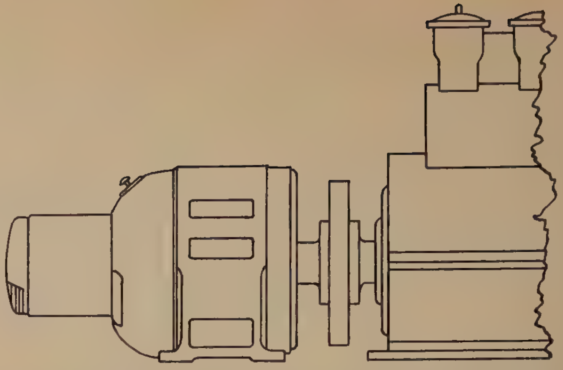


Fig. 3. Surveyor's mounting with single-bearing generator and direct-connected exciter. The solid coupling is rigid torsionally and angularly, and requires careful alignment

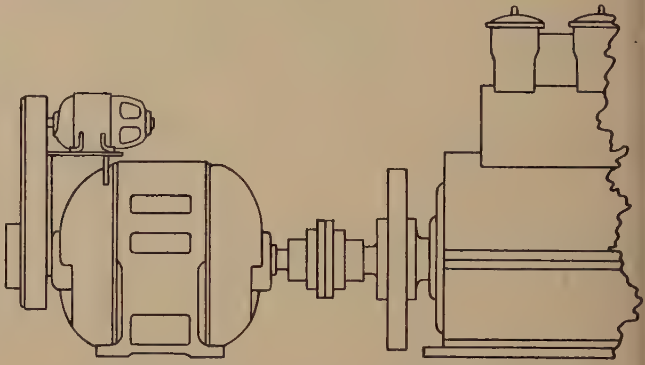
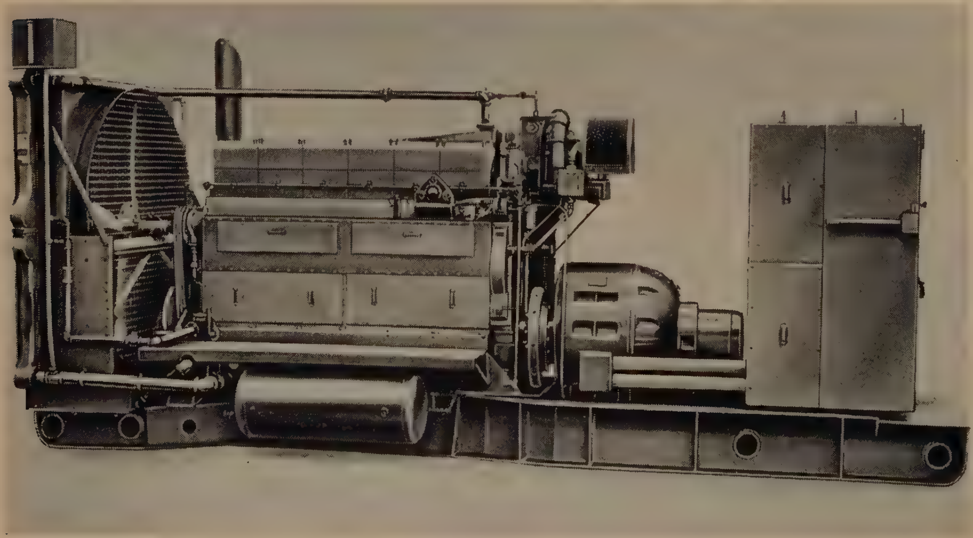


Fig. 4. Surveyor's mounting with a two-bearing generator and a top-mounted belt-driven exciter. The flexible coupling is rigid torsionally but provides for both angular and offset misalignment

The preceding two paragraphs generally apply to generators which are of bearing-bracket construction and have speeds of 500 rpm and above. These are built with shaft and bearings, and usually are equipped with a direct-connected overhung exciter or a top-mounted belt-driven exciter.

Above 800 kw or at speeds below 500 rpm the generators are generally single-bearing, with rigid coupling for



Skid-mounted 500-kw engine-generator set with single-bearing generator and rigid coupling surveyor's method of mounting. In this class of generators, since bracket-type bearings are not always available, pedestal bearings are used. Shafts and bearings are often furnished by the engine builder instead of by the generator manufacturer. Frequently, especially on low-speed machines, direct-connected foot-mounted exciters are replaced by exciters that are belt-driven from a large sheave or pulley on the generator shaft. This materially reduces the required exciter size, since a higher exciter speed can be utilized.

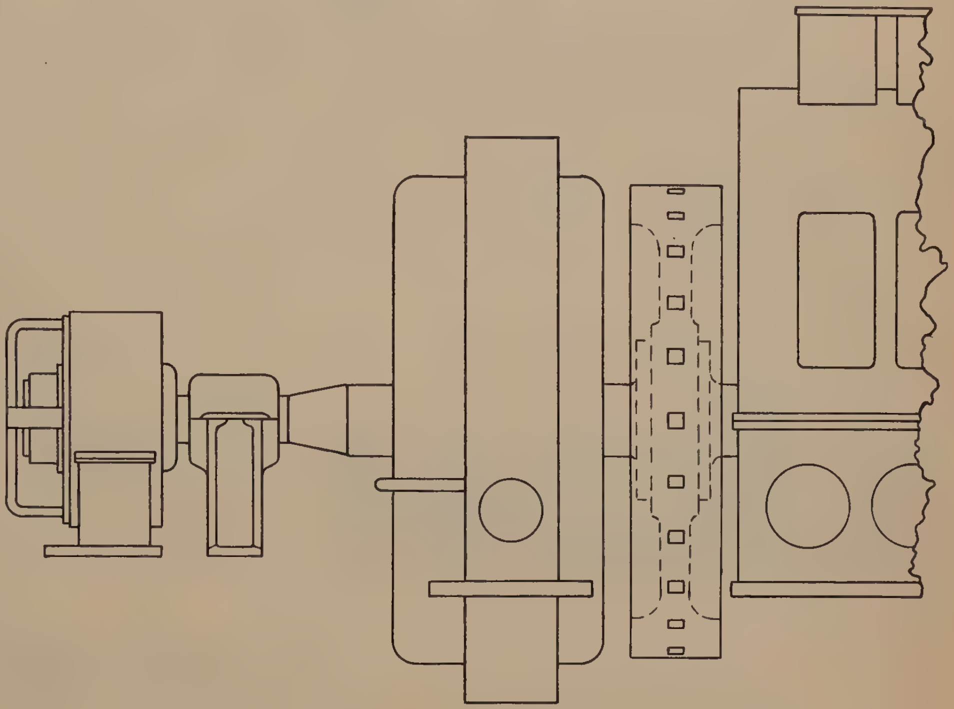


Fig. 5. Surveyor's mounting with a pedestal-bearing generator and a direct-connected exciter. The solid coupling is rigid torsionally and angularly, and requires careful alignment

TORSIONAL VIBRATION

Today practically all applications of engine-generators by engine builders involve a direct connection to a diesel engine. This makes necessary the design of a mass elastic system (crankshaft, flywheel, and generator shaft and rotor) whose torsional natural frequency will not be too close to any forced frequencies produced by the engine. Obviously, it is desirable to so design the mass elastic system that the natural frequency will be above any appreciable impulse frequency produced by the engine.

Ordinarily the engine design is established, and the generator inertia (WK^2)—being a function of machine size—is also rather well fixed, by the rating. Therefore, about all that can be changed are the generator-shaft diameter and length and the engine flywheel. Occasionally the maximum permissible change in these variables would not be enough to shift the natural frequency of the system sufficiently above the operating frequency, and in such instances resort is sometimes made to the use of couplings to provide damping or torsional flexibility. This is an exception, however, and in the vast majority of cases connection is made to the engine by one of the methods referred to earlier.

Throughout the engine-manufacturing industry it is standard practice to so co-ordinate the assembly of the engine and its driven equipment that there will be no harmful torsional vibration (20 percent has been used by the engine industry) too near the normal operating speeds. Although engine-driven generators may be manufactured with such specific features as shrunk-on spiders, dynamically balanced rotors, specially designed high-strength steel shafts, strong fans, accurate machining, and well-braced windings to minimize the undesirable effects imposed by the torsional characteristics of the engines, the generator manufacturer cannot assume responsibility for freeing the engine-generator sets from serious critical conditions. This is a responsibility which must rest with the engine manufacturer, because it is he who makes the study of the mass elastic constants of the complete engine-generator assembly.

To enable the engine builder to carry out his responsibilities on torsional factors, a shaft sketch or drawing showing distributed weights and WK^2 data for the generator rotor is usually prepared and submitted to the engine builder.

The generator manufacturer should receive approval of these data from the engine builder before building the generator. The matter of torsional approval is extremely important for all engine-driven applications, because an engine-generator set operating at, or too close to, a critical speed is doomed to failure—a broken engine or generator shaft or excessive vibration, with all the possible complications that may arise.

PARALLEL OPERATION

When alternating-current generators of the synchronous type are operating in parallel they are held in synchronism with each other by an electric "coupling" that acts through the common bus and tends to hold

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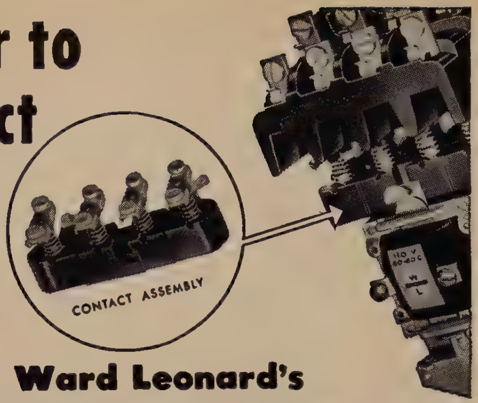

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ENGINE-DRIVEN GENERATORS

(Continued from preceding page)

the rotors of the various machines together in their rotation. This coupling is not rigid, and acts somewhat as though it contained a torsion spring. Thus the electrical system is equivalent to a mechanical system consisting of a number of rotating masses (inertia) connected to a common shaft (the bus bars) by torsionally flexible couplings. Such a system will have one or more natural frequencies of oscillation. If the torque impulses of an engine driving one of the generators has a frequency close to a natural frequency of the system, the system will oscillate and severe power pulsations may occur between the various generator units. This may cause excessive heating of the generators and sufficient voltage variation on the bus to produce flickering of lamps on the power system. Such difficulty is avoided by providing the proper amount of flywheel effect (WK^2) on the various units to limit the power pulsation to a safe value.

Since many of the factors which affect the parallel operation of generators are contained in the engine, and any additional flywheel effect necessary is usually furnished with the engine, it is the usual practice for the generator manufacturer to furnish the engine builder with such information as he may require, and for the engine builder then to assume responsibility for successful parallel operation.

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ELECTRICAL TESTING OF CAPACITOR PAPER

New test method shortens time required in acceptance and development testing of paper. Test data permit calculation of the change in power factor and dielectric constant on impregnation

By HAROLD S. ENDICOTT
Transformer and Allied Products Laboratory
Pittsfield Works, General Electric Company

Harold S. Endicott

CAPACITORS are being made in ever increasing quantities for a wide variety of applications. To insure satisfactory performance every material entering into their manufacture must undergo rigorous tests. This is especially true of the kraft paper usually used as the dielectric.

Electrical tests can be made with the paper either impregnated or unimpregnated. For many years it was the practice to test a lot of paper by using it as the dielectric in sample capacitors which, after being vacuum-dried and impregnated, were subjected to various electrical tests. This procedure had the disadvantage that the paper must be cut into rolls for winding and involved considerable time in getting the capacitors wound and impregnated. There was also the possibility of introducing unknown variables by the vacuum treatment and by the impregnant.

In power-factor measurements, these disadvantages are eliminated by making the tests on unimpregnated paper. By this method the paper is first vacuum-dried and its power factor then measured as a function of temperature without removing the sample from the drying chamber. Some of the early data obtained in this way were reported in a REVIEW article(1).

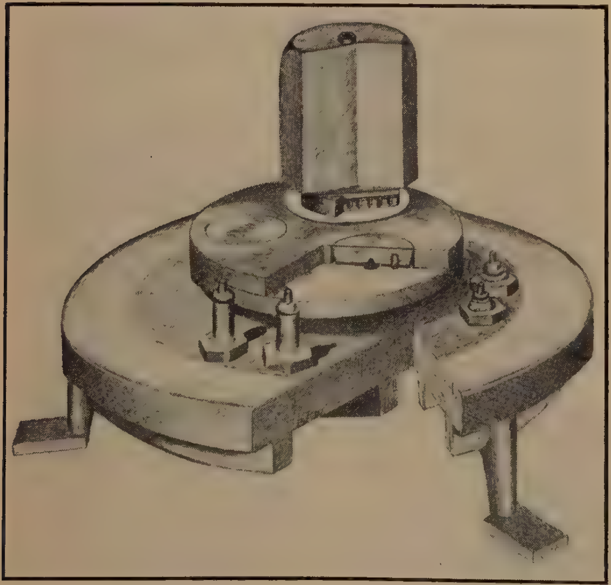

Fig. 1. Sketch showing cut-away sections of the electrode set-up used in testing capacitor paper

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

Power factor is used as the measure of the electrical quality of capacitor paper because the power factor of a capacitor represents the fraction of its kva rating which appears as heat, and heat is one of the chief limitations in the design of a-c capacitors. The relation between the power factor of the unimpregnated paper and that of the capacitor made from it has been established.

APPARATUS

The apparatus used in making power-factor tests on unimpregnated capacitor paper consists essentially of suitable electrodes, vacuum-drying chamber, and a sixty-cycle bridge for making the measurements.

The material selected for the electrodes was Trodaloy. This was done in the belief that it would eliminate trouble experienced with brass in earlier work, due to warping during the repeated temperature cycles. It has proved entirely satisfactory. High thermal conductivity was also desired to maintain as nearly uniform a temperature as possible over the electrode area. It was thought that the electrode material, per se, would have no effect on the test results. Subsequent tests with platinum-plated and with chromium-plated electrodes confirmed this. Films found on the electrode surfaces after many tests are due to material distilled from the paper rather than to corrosion of the metal.

Electrodes

The construction of the electrodes is shown by the sketch in FIG. 1 and by photograph in FIG. 2. Each set-up consists of three 1.950-in. diameter measuring electrodes and three 2.5-in. diameter high-voltage electrodes, permitting three samples to be dried and tested at one time. The measuring electrodes are insulated from the lower guard plate by sheets of mica about one or two mils thick and from the surrounding guard electrode by a four-mil air gap. The mica serves to raise the measuring electrodes above the guard so that the guard carries little of the weight of the high-voltage electrodes, thus reducing the weight required to obtain a pressure of 3 lb per sq in. on the sample. A ⅛-in. hole is drilled rom the edge to the center of the guard plate to receive a thermocouple for temperature measurement.

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(1)Numbered references are listed at the end of the article.

If the upper electrodes could be held above the samples during the drying period and lowered for the power-factor measurements, moisture could be removed much faster than is possible for samples tightly held between the electrodes. This would be perfectly satisfactory for paper one mil or more thick. However, unless it is dried under pressure, thin capacitor paper is distorted so much by drying that no reasonable electrode pressure during measurement will restore it to ts original smoothness.

The drying rate can be considerably improved by drilling a series of small holes through each upper electrode to facilitate the escape of moisture from the paper.

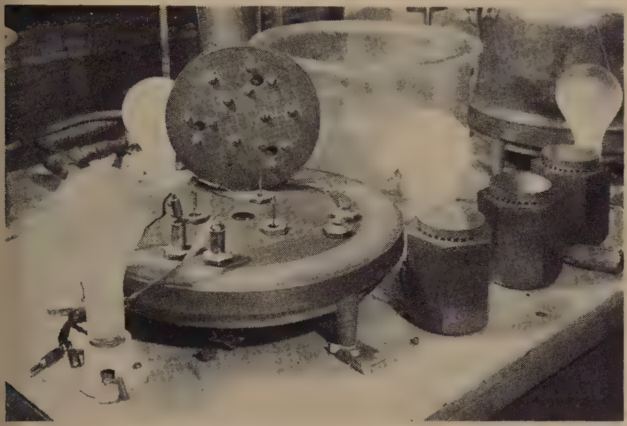
Fig. 2. Disassembled test equipment. The electrodes (at right) have been removed to show their construction and the method of bringing leads into the test chamber

These vents are ⅛-in. holes on ¼-in. centers drilled nearly through the electrodes and 13-mil holes drilled the rest of the way through the surface. Slots are cut on the back connecting the holes so that they will not be blocked by the weight used to apply pressure (about three pounds per square inch) to the sample.

The whole electrode assembly is supported on three metal-to-glass sealed bushings which pass through a base plate (Fig. 2). Other bushings provide for the high-voltage and guard leads and for the thermocouple connections. The thermocouple wires are continuous through the bushings to avoid any temperature errors at this point. Steel was originally used for the base plates but caused considerable trouble due to warping. Cast-iron plates were substituted for the steel and have been quite satisfactory.

Vacuum Chamber

A standard Pyrex desiccator is used as the vacuum chamber. The seal between it and the base plate is made very simply by placing a length of 0.012-in. fuse wire, lightly coated with silicone grease, around the base of the desiccator and overlapping the ends. The grease serves to hold the wire in place while the desiccator is being turned over and also to make a vacuum-tight seal until the pressure on the fuse wire has forced it into all irregularities. Because of the small diameter of the fuse wire it is necessary that the surfaces of the base plate and desiccator be lapped together initially until a good contact is obtained.

When all connections are tight, the pressure (exclusive of water vapor) can be reduced to ½ micron as read on a McLeod gage. A Pirani gage is also included in the system so that the total pressure may be read.

The electrodes and samples are heated by radiation from the outside. Three 150-watt lamps raise the temperature of the electrodes and samples to about 100C in five or six hours. A time switch then connects the lamps to a Variac adjusted so as to hold the temperature at 105 to 115C. Each desiccator and set of lamps is enclosed in an aluminum-foil-lined cylinder to reflect the heat into the electrodes.

Although the drying temperature is not critical, the present method of control is being improved by the installation of a potentiometer recorder-controller. Using the thermocouple imbedded in the guard plate as the actuating element, the temperature can be held to less than one degree C variation. The same instrument can be used to measure the electrode temperatures at which the power-factor readings are taken.

Sixty-cycle power-factor and capacitance measurements are made by means of a Schering bridge (Fig. 3.) The bridge circuit is conventional(2), except that the fixed resistor is made slightly inductive. This permits a balance to be obtained on zero-power-factor samples, such as guarded air capacitors. The resistance-capacitance coupled amplifier used as the balance indicator comprises five stages of amplification and is battery-operated. A tuned feedback circuit gives 60 db attenuation to the third harmonic. The hearing-aid-type

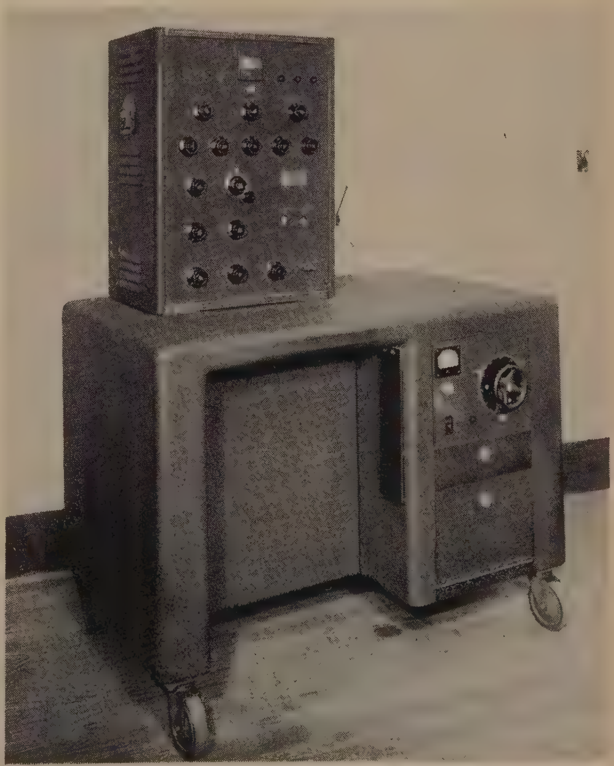
Fig. 3. Schering bridge on a portable test table containing the standard air capacitor, power supply, and controls

batteries used for the plate supply last about a year if the amplifier is turned off between readings.

The capacitance sensitivity of the bridge at 500 volts is about 0.01 per cent. The power-factor sensitivity is 0.000005 for values up to about 0.01. The accuracy depends on how closely the values are known for the standard air capacitor and for the bridge arms. Checks with the Bureau of Standards have been within ±0.02 per cent for capacitance and ±0.00002 for power factor.

TEST PROCEDURE

Because of the small size of the samples, great care is necessary in handling them to prevent contamination or wrinkling. Sufficient sheets are selected to give a nominal thickness of four mils. After inspection to make sure that no wrinkles, lumps, or other defects are included, a three-inch-diameter section is punched out. Three such samples are placed between the three sets of electrodes in each desiccator. FIG. 4 shows two samples in place in the left desiccator of a group of three.

Heat is turned on and the vacuum pump started and left on overnight (16 to 18 hr). In the morning the vacuum is broken slowly with air which is drawn through a drying train consisting of a gas-washing bottle filled with H_2SO_4, a bottle containing activated alumina and a bottle filled with glass wool and P_2O_5. As soon as the vacuum is broken, power-factor and capacitance readings are taken on all samples. The heat is then turned off and the outer cylinder removed. Additional readings of power factor and capacitance vs. temperature are taken as the samples cool to room temperature.

(Readings could be taken without breaking the vacuum except for the vibration of the electrodes due to the vacuum pump. This vibration causes the capacitance of the samples to vary, thus making the bridge balance unsteady and preventing accurate power-factor readings. No trouble would be encountered due to corona at the low pressures usually attained.)

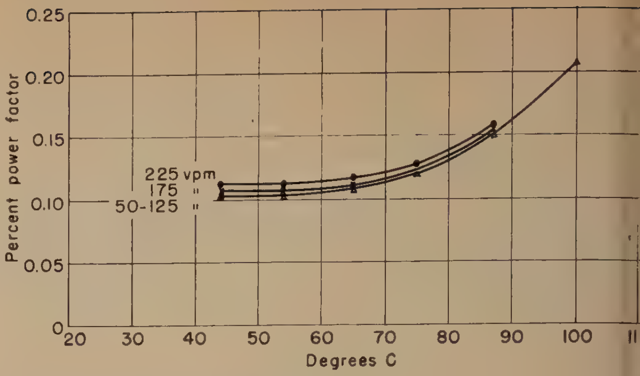

Fig. 5. Curves showing effect of voltage stress on power-factor variation with temperature for linen capacitor paper

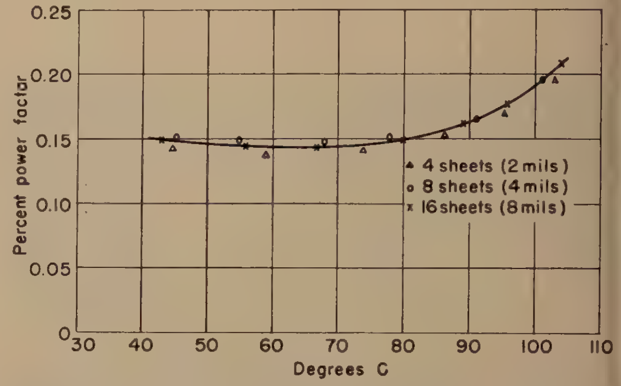

Fig. 6. Power factor versus temperature curve for kraft capacitor paper shows little change with variation in pad thickness

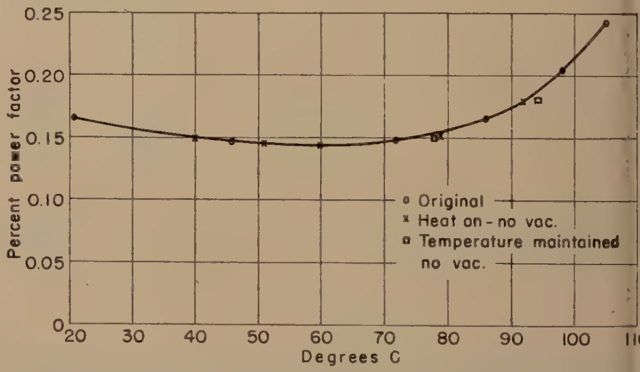

Fig. 7. Power factor versus temperature curve for kraft capacitor paper shows high degree of constancy under repeated heating and cooling

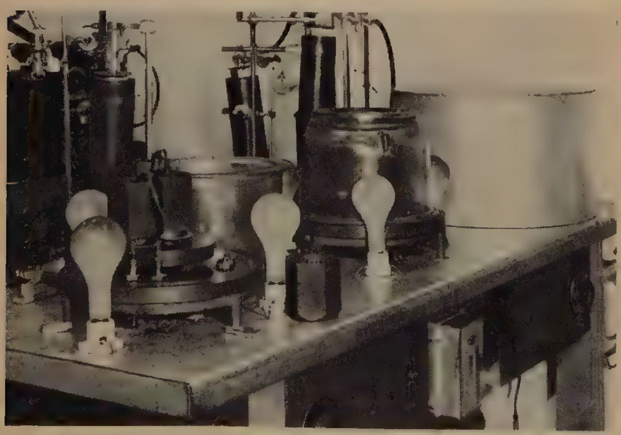

Fig. 4. General view of capacitor-paper power-factor acceptance testing equipment, showing three stages of preparation for a run. At left, exposed electrode and two samples in place; and (at right) complete set-up

At the conclusion of the electrical tests, the samples are taken out one at a time and a 2½-in. diameter section punched out and placed in a weighing bottle. The weight and thickness of these samples are subsequentl determined and the apparent density calculated. Th density is termed a "dry-dry" apparent density b cause the dimensions as well as the weight are dete mined in the dry state. This is in contrast to the usu "dry" apparent density for which the area and thickne of the paper are determined in a humidity of 50 percer and the weight after drying in an oven at 100C.

The thickness used in the calculation of density measured by means of a Federal dead weight micron eter with a pressure of 25 lb per sq in. This same valu of thickness is used in the calculation of dielectr constant from the capacitance readings. The constai so obtained is low because the actual separation of tl electrodes is greater than the measured thickness of tl samples—a difference due to the lighter pressure use

3 instead of 25 lb per sq in.), and to the fact that the neasured thickness is the average of ten micrometer eadings, whereas the electrode separation is deternined by the high spots. However, the dielectric contants so obtained on similar papers will be comparable. Whenever abnormally low values of dielectric constant are found, examination of the sample will usually show a wrinkle or lump.

Preliminary Results on Validity of Test Method

Factors which it was thought might affect the significance and reproducibility of the results were investigated first. Such factors are applied voltage, thickness of the sample, and thoroughness of drying.

Power factor and capacitance are usually measured at 500 volts (125 vpm based on nominal thickness). Fig. 5 shows power-factor vs. temperature curves made at various voltages. Up to 700 volts (175 vpm) there is very little effect of voltage on power factor. Normal variations in nominal thickness will thus cause no error in results from this cause.

Fig. 6 shows that the thickness of the sample used is not important except for very thin samples, in which case the deviations of the electrodes from absolute flatness affect the results. Differences in the air films at the electrode surfaces due to differences in surface roughness are not especially important for calendered paper.

That 16 hr is sufficient to dry the paper thoroughly, or at least to bring it to an equilibrium condition, has been shown by doubling the drying time. No change in the power factor vs. temperature curves has been observed.

Delavanti and Hansen(3) found power-factor values much higher than those reported here. Their curves also showed hysteresis loops. They attributed this to residual moisture and concluded that drying at one micron pressure was inadequate. However, the present work indicates that their drying temperature and/or time were inadequate. When paper has been vacuum-dried (100 microns or less) at 100C or higher for 16 hr, and the drying chamber does not leak, no such hysteresis has been observed. This is clearly shown in Fig. 7 which shows the power factor vs. temperature relation for kraft paper which was dried and then taken through the temperature cycle several times. On the first temperature cycle, power-factor readings were taken as the sample cooled to 46C. It then remained at atmospheric pressure and cooled to 20C overnight. A second set of readings was taken during the next day as the sample was heated to 92C. It was kept at that temperature overnight and the final two points were taken the following day as the sample was allowed to cool. The desiccator was connected to the atmosphere through the drying train and to the vacuum pump during the entire time after the vacuum was broken initially.

Pressure variation between runs has been found to be unimportant in the range of 1 to 100 microns, as read on a McLeod gage. Neither has a liquid-air trap been necessary. In the early stages of the investigation P_2O_5 was used to dry the air admitted to the samples. A liquid-air trap was later put in the vacuum line to the pump and used for several years. When breaking the vacuum the air went through the liquid-air trap after passing through the P_2O_5. Due to the inconvenience of maintaining the trap over week ends it has not been used for the past year. Absolutely no difference in results was noted at any time which could be attributed to the presence or absence of the trap.

Reproducibility of results is shown by the curves in Fig. 8. These were made by two different laboratories having similar equipment and using samples of paper from the same sample pad. Agreement is generally within ±0.01 percent power factor.

Correlation with Impregnated Paper

It has been shown that the power factor vs. temperature curves obtained are unaffected by normal variations in test conditions and are accurately reproducible. It remains to be shown that the power factor vs. temperature curves of impregnated capacitors are directly related to the curves of the unimpregnated paper.

Fig. 9 shows power factor vs. temperature curves for modified kraft paper(4) and for Pyranol impregnated

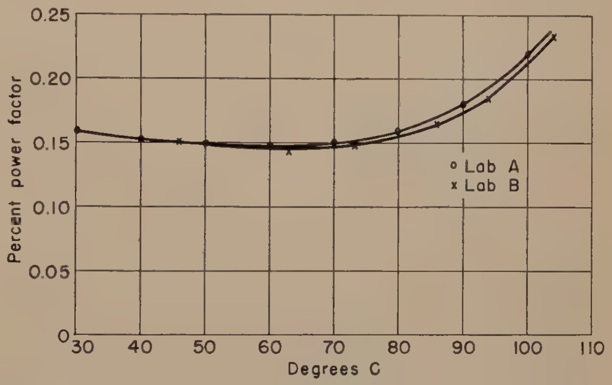

Fig. 8. Power factor versus temperature curves showing close agreement of tests made in two laboratories

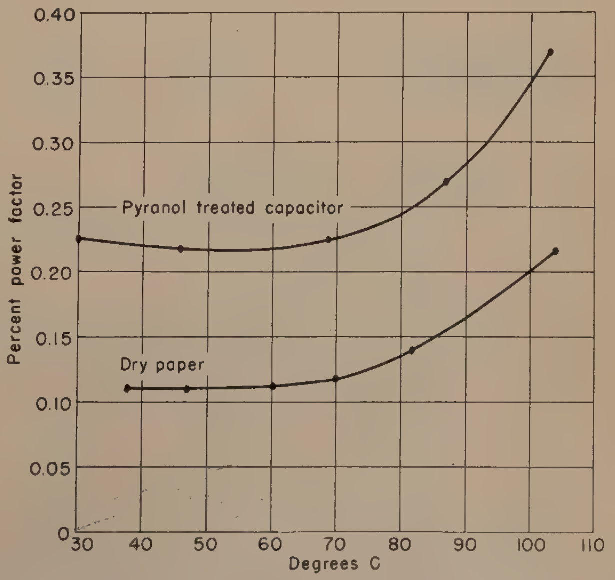

Fig. 9. Comparison of power factor versus temperature curves for dry modified kraft paper and those for the impregnated paper

modified kraft. Similar curves for a special kraft paper are shown in FIG. 10. The close similarity between the curves for the unimpregnated and the impregnated paper is quite evident. The translation of this similarity into a direct numerical relation will be considered in a later section of this article.

Acceptance Tests

On the basis of the preliminary work, a procedure for acceptance testing of all lots of capacitor paper was set up. To avoid handling and possible contamination, samples are cut as pads from the mill rolls and sent in by first-class mail for test.

Tentative acceptance limits were set up for the power factor vs. temperature curve based on the first fifty lots tested. After several hundred lots had been tested, the limits were reduced to values which it was thought should not be exceeded by normal paper. This test has now been in use for several years with very satisfactory results. When lots of paper have failed to meet the specification, investigation has almost always disclosed the source of the trouble.

A very good example of this occurred several years ago. Paper from one mill began to show higher than usual power factor at 100C. About three percent of the lots were higher than the acceptance limit and all were above normal. The trouble was finally traced to an unintentional change in the water supply to the mill. The former source was restored and subsequent paper lots were satisfactory.

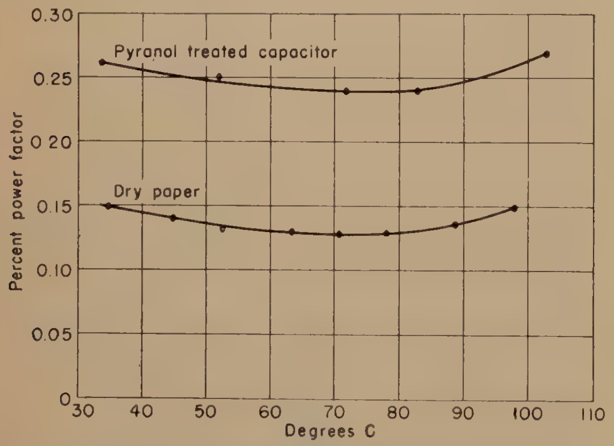

Fig. 10. Comparison of power factor versus temperature curves for a special dry kraft paper and those for the impregnated paper

TABLE I

EFFECT OF WATER ON POWER FACTOR

Distilled Water		River Water	
Temperature (C)	Percent Power Factor	Temperature (C)	Percent Power Factor
109	0.160	110	0.199
89	0.123		
71	0.113	88	0.145
59	0.113	53	0.131
41	0.127	41	0.139

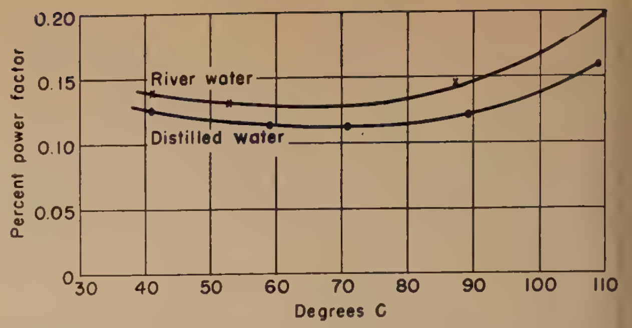

Fig. 11. Power factor of hand sheets as affected by purity of water used in the beater

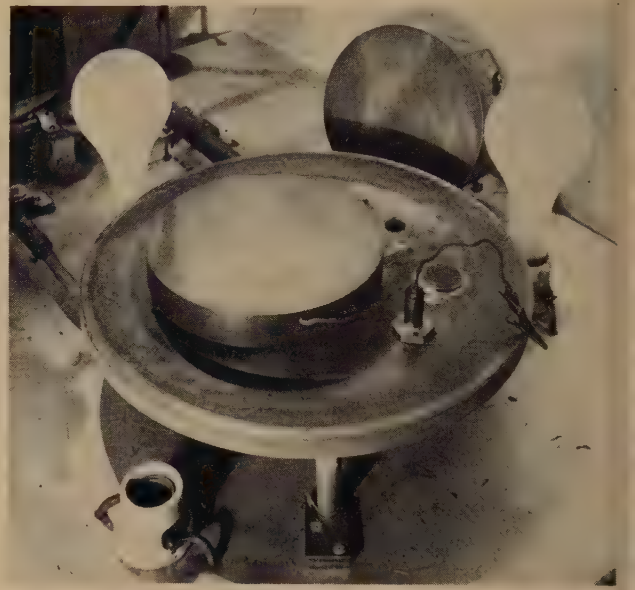

Fig. 12. Special electrode for thickness measurements of capacitor paper during power-factor acceptance tests

Testing of Hand-made Sheets

In addition to acceptance tests on capacitor paper tests are also made on hand-made sheets of paper These are made as a check on the pulp, development o new pulps(4), or as a check on some of the factors involved in paper making. The density of hand sheets i usually lower and more variable than that of calendere paper; but by correcting the results to a commo density, by means of the formulas given in a later section, very valuable information can be obtained.

For example, the effect of the water used in the beate on the power factor of the paper is readily apparent Table I gives the results of power-factor tests on han sheets made using distilled water and those made usin river water. The curves are plotted in FIG. 11. Th distilled water used had a resistivity of about 500,00 ohm-cm compared with 30,000 ohm-cm for the rive water.

DIELECTRIC CONSTANT VS. TEMPERATURE

Although the equipment described is quite satisfactory for routine testing, it is highly desirable to b able to measure the electrode separation while th samples are still in place. All measurements showe that the *capacitance* of the paper *decreased* as th temperature decreased. This had been found by some previous investigators(5) and was accounted for by assuming that the thickness of their cylindrical samples increased with decreasing temperature. Garton(6), using flat disk electrodes, also found this change in capacitance. In neither case was the actual separation of the electrodes known.

To provide this information, a new set of electrodes was built with provision for measuring the separation electrically. FIG. 12 shows the complete set-up. The 2.529-in. diameter central electrode is covered by the paper sample and it in turn supports the upper electrode. Three 1.005-in. diameter electrodes are equally spaced around the central electrode and well beyond the edge of the paper sample. Since they are entirely in air, the electrode separations can be calculated from the capacitance readings and the diameters. Since capacitance is inversely proportional to separation and also inversely proportional to the Schering bridge reading, the Schering bridge reading is directly proportional to the separation. By proper adjustment of the fixed arm of the bridge, the separation in mils can be read directly on the variable arm with 1000 ohms equal to 1 mil.

TABLE II

THICKNESS VS. TEMPERATURE

Temperature (C)	Cellulose Acetate (Thickness in mils)	Temperature (C)	Kraft Capacitor Paper (Thickness in mils)
34	4.644	32.5	4.177
46	4.657	44	4.177
59	4.677	52	4.177
71.5	4.697	67	4.181
93	4.731	78.5	4.185
111	4.785	98	4.201
		110	4.227

The sensitivity is 0.001 mil but the absolute accuracy depends on the accuracy with which the electrode diameters are known and on the flatness of the electrodes. After machining, the electrodes were lapped by hand so that they are probably flat to better than 0.01 mil. There is also some deflection of the electrodes due to the weight. A check was made by supporting the upper electrode on three small pieces of 0.005-in. cellulose acetate. The electrode separation as determined by the three small electrodes agreed with that determined by the central electrode within 0.5 percent.

Table II gives the data obtained on the thickness of cellulose acetate and kraft capacitor paper at various temperatures. The data are shown graphically in FIG. 13. Thicknesses have been corrected for the linear thermal expansion of the electrodes (0.003 percent per deg C). FIG. 14 shows dielectric constant vs. temperature curves for kraft capacitor paper, based on the electrically measured thicknesses and also corrected for electrode expansion. This demonstrates quite clearly that the *dielectric constant* of kraft capacitor paper *decreases* as the temperature decreases.

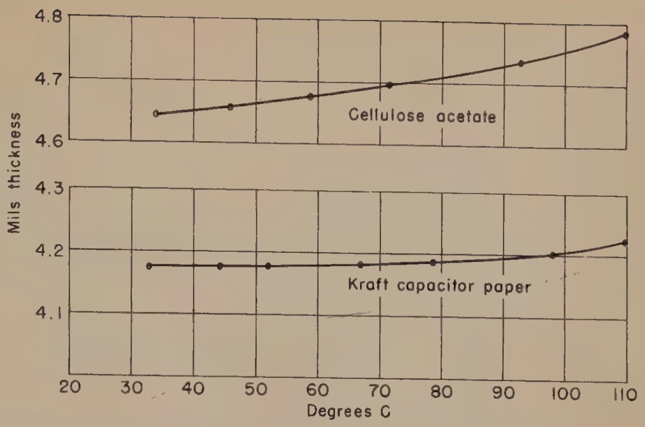

Fig. 13. Thickness versus temperature curves for cellulose acetate and kraft capacitor paper

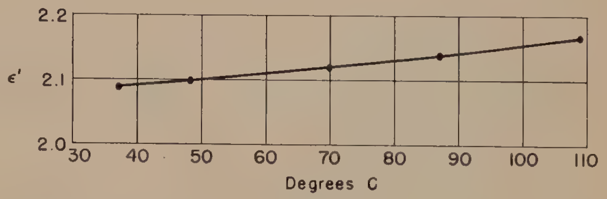

Fig. 14. Dielectric constant versus temperature curve for kraft capacitor paper

TABLE III

DIELECTRIC CONSTANT VS. DENSITY OF KRAFT PAPER

Density (Grams per cc)	ϵ'	Density (Grams per cc)	ϵ'
0.25	1.18	1.01	2.36
0.66	1.63	1.04	2.43
0.84	1.90	1.06	2.44
0.95	2.22	1.08	2.50
0.96	2.19	1.09	2.55
0.97	2.20	1.10	2.58
0.99	2.34	1.10	2.62

EFFECT OF SHEET DENSITY

One of the problems given special consideration was the relation between sheet density, power factor, and dielectric constant. Evidence presented in an earlier article(1) led to the conclusion that the paper fibers and air, or impregnant, form a purely series combination, for which

$$\epsilon' = \epsilon_f'\epsilon_i'/(\theta_f\epsilon_i' + \theta_i\epsilon_f') \qquad (1)$$

and

$$\mathrm{PF} = \theta_f\epsilon_i'\ (\mathrm{PF}_f)\ /(\theta_f\epsilon_i' + \theta_i\epsilon_f') \qquad (2)$$

where ϵ' is dielectric constant, PF is power factor, and θ is the fractional volume. Subscripts f and i refer to fiber and impregnant respectively and the quantities without subscripts refer to effective values for the combination. The power factor of the impregnant is considered to be negligible.

By use of Formula (1), the solid curves in FIG. 15 were calculated to show the relation between ϵ' and sheet density for the cases $\epsilon_i'=1$ (air) and $\epsilon_i'=\infty$. The paper fibers were assumed to have a density of 1.50 and a dielectric constant of 6.6. This value of dielectric constant is based on measurements made in the writer's laboratory. It is in reasonable agreement with the figure of 6.24 calculated from the data reported by Maass(7) as his measurements were made at a frequency considerably above 60 cycles.

Test values for unimpregnated kraft paper are given in Table III and are indicated by crosses near the lower solid curve in FIG. 15. Both the apparent density and the dielectric constant are based on the measured separation of the electrodes. When it became possible to impregnate paper with a liquid having the effect of infinite dielectric constant (a semiconductor)(8) the points marked by the crosses above the upper solid curve were obtained. The divergence of the upper points from the curve based on the simple series relation is quite evident.

A further discrepancy was pointed out by McLean, Egerton, and Houtz(9) on the basis of a great many measurements made before and after impregnation. They found the ratio

$$(\mathrm{PF}_i/\mathrm{PF}_u) \div (C_i/C_u) = 0.9 \text{ to } 1.0 \qquad (3)$$

for a hydrocarbon wax and less than 0.9 for chlorinated naphthalene. The terms PF and C refer to power factor and capacitance and the subscripts i and u refer to the impregnated and unimpregnated condition respectively. Calculations based on zero loss in the impregnant and series relation between paper and impregnant give a value of 1.0 for this ratio.

A clue to a possible explanation may be found by examining a cross section of a single sheet of capacitor paper under a microscope or by measuring its thickness by means of a micrometer having a fine ball anvil. The thickness is found to vary as much as four to one from one area to another. When many sheets are used to form the dielectric, the over-all variation from point to point must be greatly reduced. However, for three-sheet dielectrics the nonuniformity may still be appreciable.

Such variations in thickness would result in the power-factor increase on impregnation being less than the capacitance increase, as was found experimentally by McLean, Egerton, and Houtz. This variation in thickness would also cause the dielectric constant of paper impregnated with a semiconducting liquid to be higher than the value calculated on the basis of a uniform thickness. A qualitative explanation of the observed facts is thus arrived at.

CALCULATION OF POWER FACTOR AND CAPACITANCE

Impregnated Paper Capacitors

Many attempts have been made to calculate the power factor of impregnated paper from measurements on the unimpregnated paper and on the impregnant, using a variety of theories to explain the combination of paper and impregnant. None of the theories has been completely satisfactory. However, as the preceding section indicates, the picture is becoming clearer.

An unimpregnated paper dielectric consists of paper fibers in series with air but with the ratio of air to paper varying from point to point over the area of the dielectric (for thin dielectrics). On impregnation, the air is replaced by the impregnant, whose contribution to the loss is considered negligible at 60 cycles over the normal range of voltage and temperature. The power factor of the combination is increased, however, because of the increased stress on the fibers.

Our knowledge of fiber dielectric constant and density is still too meager to permit exact calculations; but the agreement with experimental results is good. Table IV shows a comparison of experimental with calculated values. The experimental values are for wound commercial three-sheet capacitors, wound with three sheets of paper having an apparent density of 1.0 and with a 10-percent liquid film. The calculations are made using

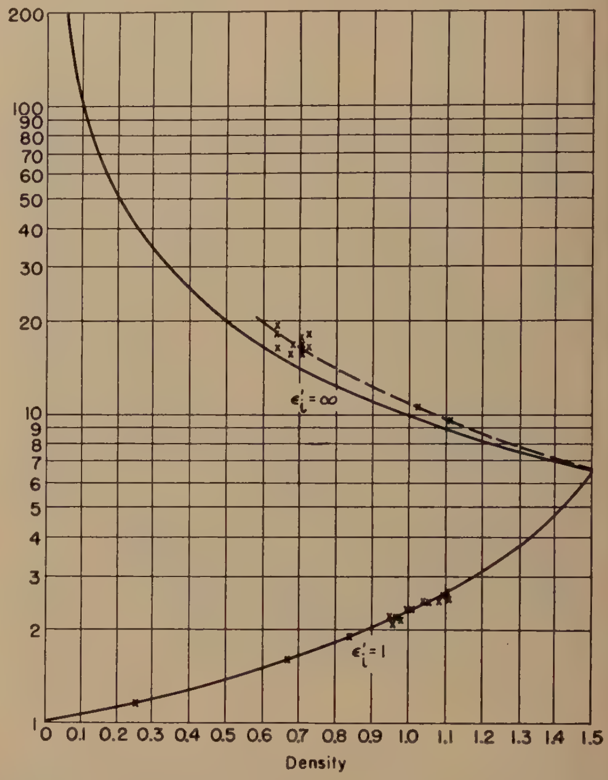

Fig. 15. Calculated curves for dielectric constant versus apparent sheet density

TABLE IV

TEST VS. CALCULATED VALUES OF CAPACITANCE RATIO AND POWER FACTOR FOR IMPREGNATED CAPACITORS

	Test	Calculated
Ratio oil treated capacitance to dry paper capacitance	1.75	1.78
Power Factor of oil treated capacitor	0.22%	0.23%
Ratio Pyranol treated capacitance to oil treated capacitance	1.58	1.58
Power Factor of Pyranol treated capacitor	0.32%	0.34%
Ratio of high-dielectric-constant-liquid treated capacitance to Pyranol treated capacitance	1.55	1.53
Power Factor of high-dielectric-constant-liquid treated capacitor	0.48%	0.49%
Ratio $(\mathrm{PF}_i/\mathrm{PF}_u) \div (C_i/C_u)$	0.9–1.0	0.93 (Pyranol)

TABLE V

CORRECTION FOR DENSITY—LOW-DENSITY SAMPLE

Temperature	Measured Percent Power Factor	Calculated Percent Power Factor
110C	0.175	0.246
100	0.140	0.197
90	0.118	0.166
80	0.104	0.147
70	0.100	0.141
57	0.099	0.139
36	0.109	0.153
	Measured	Calculated
Electrode separation—mils	4.79	....
"Dry dry" apparent density	0.85	1.00
Dielectric constant	1.93	2.31

TABLE VI

CORRECTION FOR DENSITY—HIGH-DENSITY SAMPLE

Temperature	Measured Percent Power Factor	Calculated Percent Power Factor
103C	0.298	0.236
89	0.220	0.174
73	0.185	0.147
63	0.180	0.143
53	0.180	0.143
40	0.186	0.147
	Measured	Calculated
Electrode separation—mils	3.84	....
"Dry dry" apparent density	1.10	1.00
Dielectric constant	2.64	2.30

Equations (1) and (2) and are based on a fiber density of 1.50, dielectric constant of 6.6, and power factor of 0.6 percent. An allowance was made for the effect of the nonuniformity of the paper thickness previously mentioned.

Unimpregnated Paper

For the proper evaluation of dielectric-constant and power-factor measurements made on unimpregnated paper it is important to eliminate the effect of sheet density. Equations based on the series relation are easily derived and do not involve the density or dielectric constant of the fibers. These are:

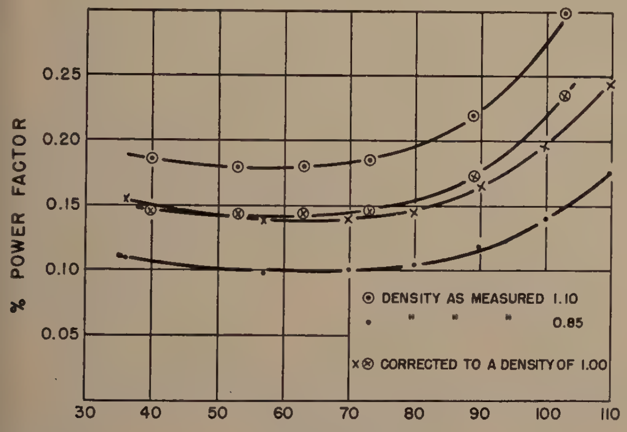

Fig. 16. Correction of power factor for density of sample

$$\frac{\epsilon'_2}{\epsilon'_1}=\frac{d_1}{d_2-(d_2-d_1)\,\epsilon'_1} \qquad (4)$$

and

$$PF_2/PF_1=\epsilon'_2 d_2/\epsilon'_1 d_1 \qquad (5)$$

where ϵ'_1 and PF_1 are the dielectric constant and power factor at density d_1; ϵ'_2 and PF_2 are those at density d_2.

Examples of the use of these formulas are given in Tables V and VI. Table V gives the measured values of power factor, dielectric constant, density, and thickness for a low-density paper, together with the values corrected to a density of 1.0. Similar results for a high-density paper are given in Table VI. The two sets of data are shown graphically in Fig. 16.

The corrected values of dielectric constant are almost identical and the power factors are quite similar. The two samples of paper were not from the same lot and would not necessarily have the same power factor.

Care must be exercised when applying these formulas to thin dielectrics and hand-made sheets as the effect of nonuniformity may be appreciable. There is also a possibility that the series formula may not always apply strictly. Intelligently applied, however, they can be a great assistance in interpreting results.

SUMMARY

Equipment has been described by means of which the dielectric constant and power factor of unimpregnated capacitor paper may be measured accurately. This equipment has been in use for a number of years for acceptance tests on capacitor paper with very satisfactory results. The time necessary for a test has been reduced from the three weeks formerly required to two days. Of equal importance is the fact that very close correlation is obtained between tests on the dry, unimpregnated paper and on the capacitors made with it. As an outcome of this work, an explanation is given of the capacitor paper-impregnant system, which permits quantitative calculation of impregnated paper power factor from the power factors of the constituents.

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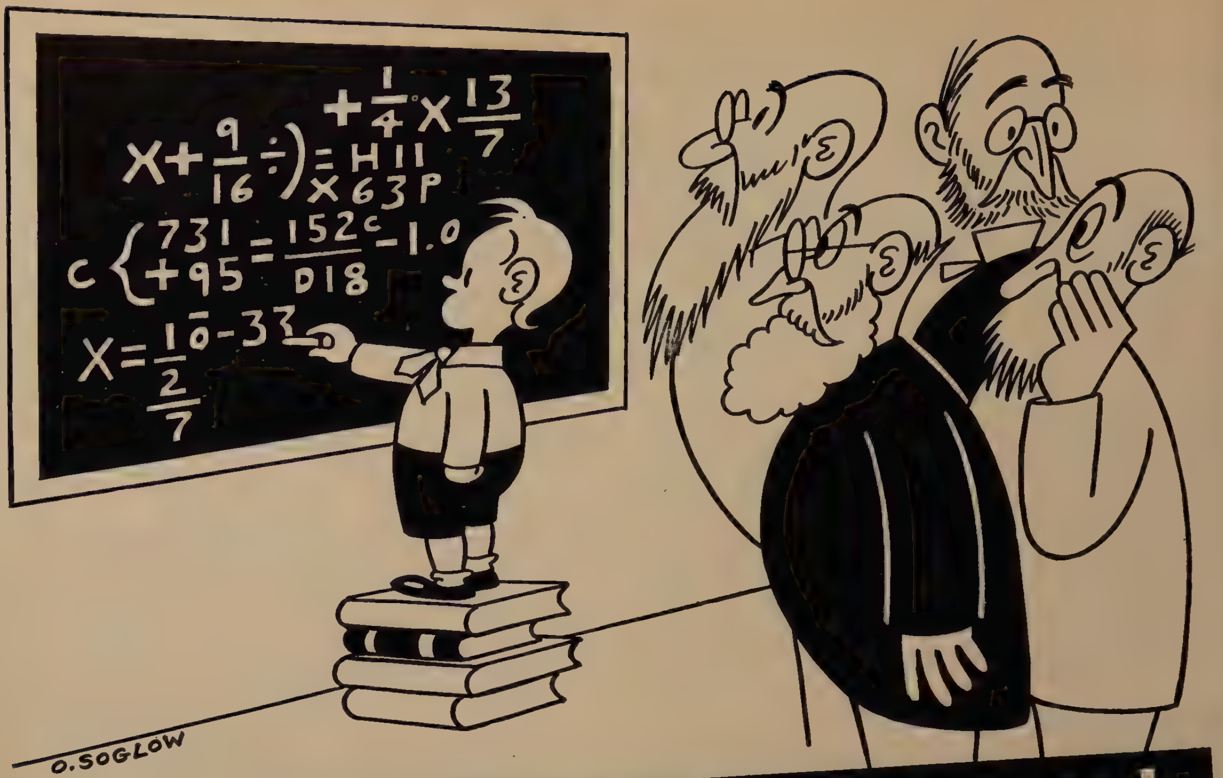

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PROTECTIVE ATMOSPHERES IN INDUSTRY . . Part X

The methods by which surplus gases can be accumulated and stored during the low-demand periods for utilization when peak demand is greatest, with emphasis on safety precautions, cost economy, and convenience in handling

By A. G. HOTCHKISS and H. M. WEBBER
Industrial Heating Divisions, General Electric Company

THE average user of protective atmospheres is probably but little concerned with the problem of gas storage. As keen competition brings more and more emphasis on cost of production, however, it becomes more important that surplus atmosphere gas, instead of being wasted, be accumulated and stored during off-peak periods to be utilized during other periods when the demand is excessive. Methods by which this can be accomplished will be described in this Part.

STORAGE

FUEL GASES

Natural Gas and Manufactured Gases. Users of natural gas and manufactured gases are not concerned with storage problems. Such gases are generally stored by the gas companies which distribute their products over wide areas, such as cities and towns, through a complicated network of piping. The gas is delivered to the user at pressures of from 6 to 8 in. up to several pounds. Natural gas is usually piped long distances from the gas field to the place of use, under fairly high pressure furnished by booster compressors located at intervals along the line. Any storage tanks used for such purposes are high-pressure tanks placed above ground. Manufactured gas is stored in constant-volume tanks of very large capacity in which the gas is maintained at a few pounds pressure, or in variable-volume holders which consist of closed, inverted vessels sealed in water.

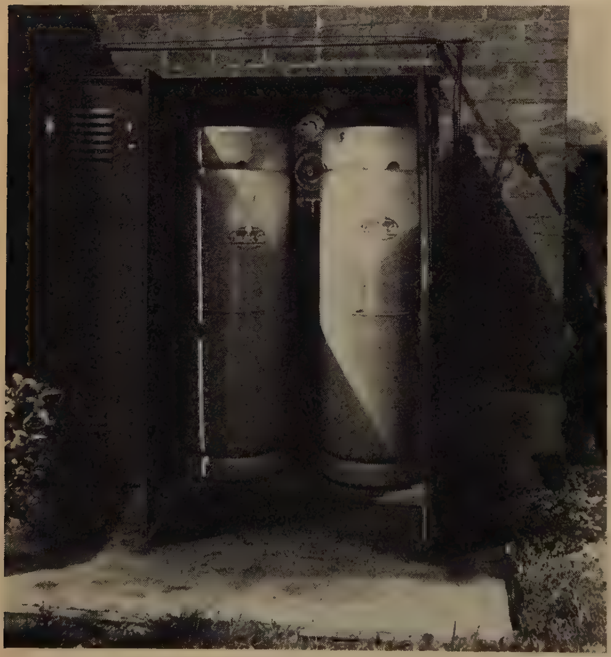

Fig. 98. A four-tank 2-cabinet propane installation furnishing gas used for gas carburizing and for atmosphere gas generators

Liquefied Petroleum Gases. Liquefied petroleum gases are in rather general use today as a source of economical fuel, which is used for general heating purposes as well as for producing protective atmospheres.

TABLE XVII

CHARACTERISTICS OF FUEL GASES

	Boiling Point at Standard Pressure F	Limits of Flammability (Percent Gas in Air) Lower	Higher	Spread	Ignition Temp. F	Specific Gravity (Air = 1)
Methane	−259	5.00	15.00	10.00	1200–1382	0.554
Ethane	−155	3.22	12.45	9.23	968–1166	1.036
Propylene	−128	2.00	11.10	9.10		1.451
Propane	−43.7	2.37	9.50	6.13	965	1.520
Butylene		1.70	9.00	7.30		1.935
Butane	+10.9–31.1	1.80	8.44	6.64	930	2.07
Natural gas		4.80	14.60	9.80		0.60–0.70
Coal gas		5.60	30.8	25.2		0.42–0.47
Carbureted water gas		6.40	37.70	31.30		0.54–0.67
Carbon monoxide	−314	12.50	74.20	61.70	1191–1216	0.968
Hydrogen	−423	4.0	74.20	70.20	1076–1094	0.069

These gases coming from natural sources consist generally of propane or butane with small amounts of ethane usually present. Such liquefied petroleum gases coming from refinery sources also contain sizable amounts of propylene or butylene.

Liquefied petroleum installations are subject to regulations as issued by the National Fire Protection Association and published by the National Board of Fire Underwriters in their Pamphlet No. 58. Some small installations consist of 100-lb cylinders used either singly or in multiple as shown in FIG. 98. The distributor is prepared to furnish the metal enclosure and the necessary pressure-reducing regulator. The service includes delivering full tanks at specified intervals and replacing the empty ones.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

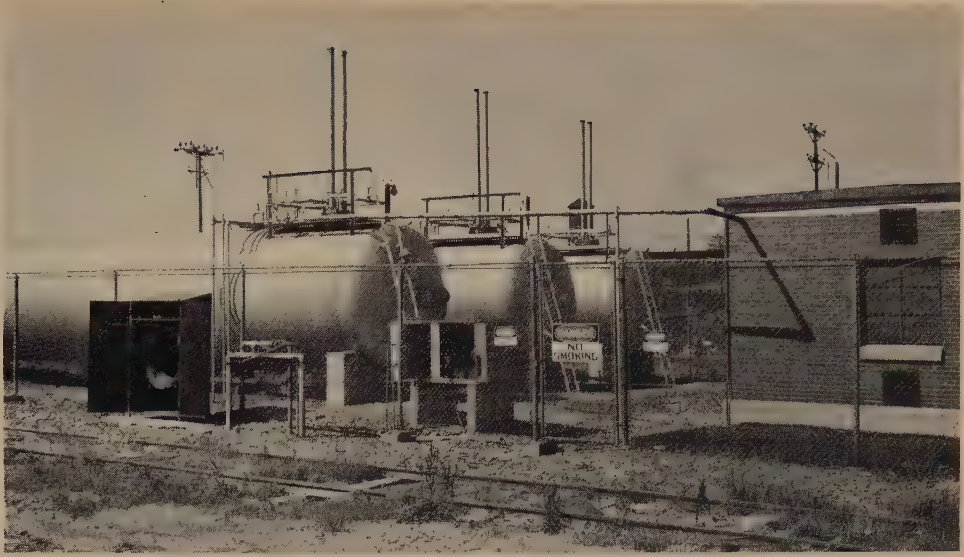

Fig. 99. A large propane storage installation used for standby fuel source. Mixing equipment located in the building dilutes the propane with air to produce a mixture suitable for substituting for natural gas

For larger installations, the liquefied fuel is delivered by railroad tank cars of approximately 10,000-gal capacity. The storage tanks range in size from 12,000 to 30,000 gal. Many installations are used as a source of standby fuel to be used only in emergency. The installation shown in FIG. 99 is such a standby equipment; it includes a mixing station which mixes vaporized propane with air in such proportions that the mixture will burn satisfactorily in burners which normally use natural gas.

From the safety standpoint, the limits of flammability(24) are less for liquefied petroleum gas than for other commercial fuel gases. This will be obvious from Table XVII which gives the characteristics of various fuel gases. For propane in air, for instance, the spread between lower and higher limits of flammability is 6.1 percent propane as compared to 25.2 percent for coal gas and 70.2 percent for hydrogen. It is also an interesting fact that the lower flammable limit for liquefied petroleum gases is lower than that for other commercial fuel gases. This means that it requires less liquefied petroleum gas in air to reach the flammable range than for other commercial fuels.

TABLE XVIII

PHYSICAL PROPERTIES OF LIQUEFIED GASES

	Lb per Gal	Cu Ft per Gal	Cu Ft per Lb	Btu per Cu Ft	Vapor Pressure, psi 0 F	70 F	100 F
Propane (C_3H_8)	4.25	37	8.58	2521	24	112	196
Butane (C_4H_{10})	4.8	31.8	6.51	3274	−4	27	55
Ammonia (NH_3)	5.08	114.3	22.5	432.8	15.7	114	197

The vapor pressure of propane as shown in Table XVIII permits storage in tanks designed for 200 psi. Even at low winter temperature conditions, the vapor pressure remains sufficiently high for normal distribution purposes.

The vaporized fuel can be withdrawn as a gas from the top of the tank through the proper regulating equipment. However, the liquid is generally a mixture of two or more liquefied gases; and the material with the lower boiling point will vaporize first, thereby giving a gas of somewhat lower Btu than that which comes off last. For this reason it is generally advisable to withdraw the liquid as such and vaporize it in a separately heated vaporizer, which results in a more uniform fuel analysis.

Fire precautions are similar to those required for any other commercial gas. It should be remembered, however, that the gas is heavier than air (Table XVII) and seeks low spots in the terrain. Likewise, its lower flammable limit is lower than for other commercial gases. It is possible, therefore, for the gas to hang closer to the floor, and to form a flammable mixture sooner than most other fuel gases. Years of experience have indicated that liquefied petroleum gases may be stored, handled, and used with the utmost safety if proper engineering standards are followed, and if the same precautions are taken as in the handling of any other fuel gas.

Ammonia. Anhydrous ammonia for ammonia dissociators (Part III*) is supplied in a liquid form. Standard small containers are in three sizes—50 lb, 100 lb, and 150 lb. If the consumption exceeds 50,000 lb per year, it is then economical to install a large tank of 13,000-gal capacity or more, and purchase the ammonia in tank-car lots. Such an installation would be very similar to that shown in FIG. 99 except that normally one tank is sufficient. Auxiliary equipment as shown

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*The following will facilitate the location of material published in earlier parts of this serial:

Part	*Issue*	*Figs.*	*Equations*	*Tables*	*Footnotes*
Part I	Nov. 1948, p. 29	1 to 6	None	I and II	None
Part II	Dec. 1948, p. 41	7 to 14	(1) to (18)	III and IV	(1) to (9)
Part III	Feb. 1949, p. 37	15 to 23	None	V and VI	None
Part IV	Mar. 1949, p. 25	24 to 35	None	VII	None
Part V	Apr. 1949, p. 25	36 to 41	None	VIII to X	(10 and (11)
Part VI	May 1949, p. 30	42 to 54	None	XI to XII	(12)
Part VII	June 1949, p. 33	55 to 70	None	XIII to XV	(13) to (17)
Part VIII	July 1949, p. 32	71 to 89	None	XVI	(18) to (23)
Part IX	Aug. 1949, p. 26	90 to 97	None	None	None

in FIG. 100 would include a compressor which is required for unloading the liquid ammonia from the tank car. Also shown in this picture is a vaporizer at the right and two 2000-cfh dissociators in the background.

The vapor pressure of liquid ammonia at 100 F is about 200 lb, practically the same as of propane (Table XVIII). It is thus possible to remove from the tank a limited amount of vaporized ammonia. If any considerable quantity is to be withdrawn, however, it is necessary to remove the liquid and vaporize it in a separate vaporizer for which heat must be supplied. Because of its toxic properties and pungent odor, ammonia must be completely confined; and minute leaks are readily detectable. Ammonia storage systems are available and are installed according to fixed regulations similar to those existing for liquefied petroleum gases. All companies supplying anhydrous ammonia have available considerable information concerning the use and the handling of ammonia for atmosphere purposes.(25)

ATMOSPHERE GASES

Tanked Gases. Hydrogen and nitrogen are often delivered in bottles, cylinders, and tubes (Part III). The outlet shutoff valves are protected by metal covers. When using these gases for atmospheres, it is desirable to place pressure-regulating valves directly at the tanks so that the pressure of about 2000 lb is reduced to not over 2 or 3 lb in the lines to the points of use. It is always desirable to protect such tanks from mechanical damage and also from excessive temperature which might increase the pressure inside the tank beyond safe values.

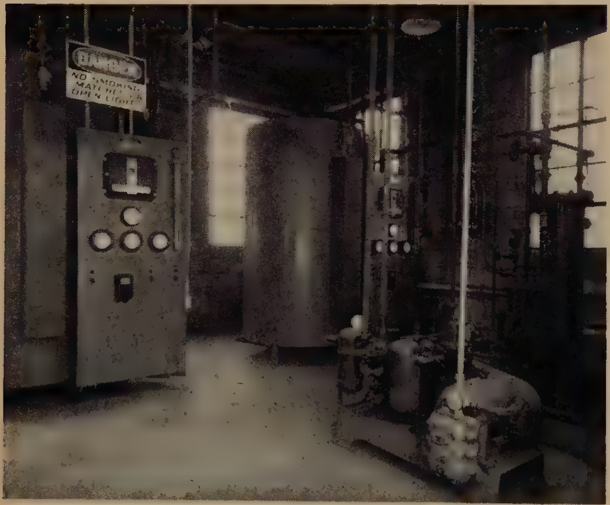

Fig. 100. Ammonia compressor used for unloading liquid anhydrous ammonia from tank car into a storage tank. The vaporizer is at the right and two 2000-cfh ammonia dissociators are shown in the background

Prepared Gases. The combusted fuel gases listed in Part I, Table I, Section E, are often compressed and stored in pressure tanks. This procedure is particularly advantageous in installations where the rate of flow fluctuates widely—for instance, in a multiple-furnace arrangement which requires a high flow of the gas for a short time every few hours for purging purposes, but a relatively small flow after purging is completed. By staggering the purging periods and properly sizing the storage tank which supplies the high rate of flow necessary for the purging period, the size of the atmosphere producer can be reduced considerably over that necessary without the storage system.

The arrangement should be such that the atmosphere producer will operate at approximately a constant output, which is the most desirable method from the standpoint of producing an atmosphere of uniform analysis. FIG. 101 shows the schematic piping diagram of such a typical atmosphere-storage system. The output of the atmosphere producer is fed to a compressor through a small surge tank. This tank serves merely as a buffer to prevent pulsations of the compressor from affecting the operation of the atmosphere producer, and allows the atmosphere producer a short time interval in which to adjust itself to volume changes as established by the compressor control. The minimum volume of this tank can be calculated from the formula:

$$\text{Tank volume in cu ft} = \frac{\text{Cu ft per hr gas to compressor}}{\text{rpm} \times \text{number of cylinders}}$$

Compression heats the gas and reduces its moisture content; therefore, the hot compressed gas is conducted through a cooler and separator and the condensate is trapped off. The pressure of the compressed gas from the storage tank is usually reduced by an automatic regulator to a pressure of a few pounds to a few ounces at the point of use.

It is desirable to select a compressor that will take just the full output of the atmosphere producer. Auto-

TABLE XIX

TABLE SHOWING RELATION BETWEEN DEW POINT AND MOISTURE CONTENT OF GASES AT DIFFERENT PRESSURES.*†

Pressure (Lb Gage)	Water Percent by Vol.	Equivalent Dew Point Temp. F (Nearest Degree)	Pressure (Lb Gage)	Water Percent by Vol.	Equivalent Dew Point Temp. F (Nearest) Degree)
0	3.46	80	220	0.216	8
10	2.02	64	240	0.198	6
20	1.45	55	260	0.183	4
30	1.125	48	280	0.171	2
40	0.922	43	300	0.161	1
50	0.778	39	320	0.151	0
60	0.670	35	340	0.142	−1
70	0.594	32	360	0.134	−2
80	0.533	29	380	0.128	−3
90	0.483	26	400	0.122	−4
100	0.440	24	450	0.109	−6
110	0.405	22	500	0.098	−8
120	0.374	20	550	0.089	−10
130	0.350	19	600	0.082	−12
140	0.325	18	650	0.076	−14
150	0.306	16	700	0.070	−16
160	0.288	15	750	0.066	−17
170	0.273	14	800	0.062	−18
180	0.258	12	850	0.058	−19
190	0.247	11	900	0.055	−20
200	0.238	10	950	0.052	−21
			1000	0.050	−22

* After compressing and removing all condensation at 80 F.
† (For additional information see Table VII.)

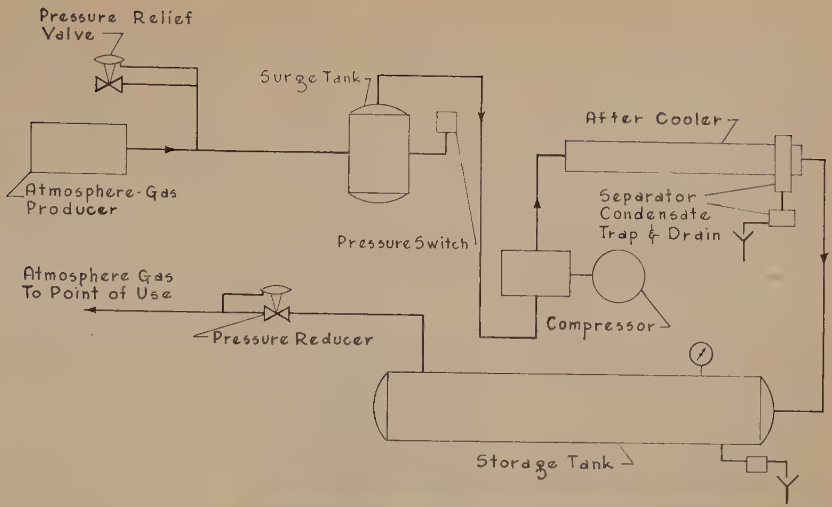

Fig. 101. Schematic piping diagram of a typical high-pressure inert-gas storage system

matic controls such as a low-pressure switch are provided, however, to prevent the compressor from pulling a vacuum on the atmosphere producer. A relief valve will automatically permit the atmosphere producer to function at approximately one-half output should the compressor stop. The size of the storage tank will depend on the capacity requirements and the pressure to which the gas is compressed. Normally, pressures of approximately 100 psi prove to be the most economical from the standpoint of tank size and cost of the compressing equipment required. Pressures up to 300 psi can be used if the application requires it.

The reduction of moisture content by compression is generally a desirable feature. The amount of moisture removed is illustrated by Table XIX; for example, a gas which is saturated at +80 F at atmospheric pressure, contains 3.46 percent water vapor by volume. When compressed to 100 lb gage, the moisture content is reduced to only 0.44 percent, which corresponds to a dew point of +24 F. Compression then eliminates the necessity for removing moisture by refrigeration and, in cases where the remaining moisture is to be removed, a small regenerative dryer will accomplish the purpose.

Fig. 102 is a photograph of a typical 5000-gal storage tank used for inert combusted fuel gas (E1b) maintained at 55-lb pressure. The atmosphere is supplied by a 3000-cfh atmosphere gas converter which is used in this instance to supply inert gas for varnish-cooking kettles, storage tanks, pipe lines, and for fire prevention. In another installation, a similar type of equipment furnishes inert gas at higher pressures to be used as a substitute for compressed air to prevent oxidation of the rubber compression molds used in the manufacture of automobile tires.

Some atmosphere furnaces require sources of standby atmospheres because of the necessity for protecting the furnaces or the products from damage due to accidental stoppage of the atmosphere-generating equipments. In such instances, where it is assumed that the generating equipment is inoperative because of power failure or fuel-gas failure, a supply of prepared atmosphere is stored under pressure and in sufficient volume to furnish a minimum requirement over the shutdown period. This requirement is particularly important where large tower and elevator furnaces contain flammable gases of high hydrogen content which might become dangerous from the explosion standpoint if the flow of the gas is interrupted. In such cases, a sufficient quantity of inert gas is stored in readiness to completely purge the flammable gases from the furnace and eliminate any hazardous condition. These precautions, which will be presented in detail in a succeeding Part under Methods of Purging, are necessary for some types of furnaces but are not needed for all types.

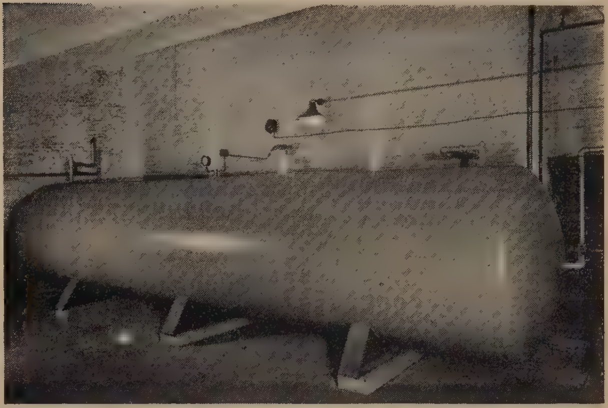

Fig. 102. A 5000-gal storage tank for storing inert gas at 55 psi. Gas produced by 3000-cfh atmosphere converter. Used for varnish-cooking kettles, storage tanks, fire prevention, etc. (*Courtesy Enterprise Paint & Mfg. Co., Chicago*)

PRESSURE AND VOLUME CONTROL

Furnace atmospheres, as obtained directly from the generators or from storage tanks, are frequently supplied at a greater pressure than that required at the furnace, and sometimes the pressure is variable, causing variable flows. It is generally desirable to reduce the atmosphere gas to some pressure which remains constant regardless of variations in flow (within limits of the producer) from the generating source.

Pressure-regulating Valves. Pressure-regulating valves are widely used in the control of all types of gases. Such valves operate (within their range) to automatically hold a constant pressure on the downstream side, even though the upstream pressure may vary considerably. The valves are usually diaphragm-operated and may be of the dead-weight or spring-loaded type. A cross-sectional view of a typical valve of the spring-loaded type is shown in Fig. 103. The diaphragm, which is clamped between the halves of the casting, divides the diaphragm chamber into two parts. The top part contains a spring which can be adjusted to exert variable pressures against the top side of the diaphragm. The valve stem is attached to the bottom side of the diaphragm and is free to move up and down through its guide. On the right side of the bottom half of the diaphragm chamber is a pipe connection which will be piped into the downstream piping. The gas entering the valve at the left or upstream side must always be at some pressure higher than that which the valve is expected to maintain on the downstream side. In operation, the spring will maintain the valve in an open position until the gas leaving the valve is throttled or closed off sufficiently to allow the pressure on the downstream side to increase. The increased pressure will be transmitted to the bottom side of the diaphragm through the small pipe connection and will close the valve when the force exerted on the bottom side of the diaphragm exceeds the force of the spring. When gas is flowing as in normal operation, the diaphragm will float in some mid-position which will open the valve only sufficiently to supply the flow demanded. When the spring pressure is increased, the pressure maintained on the downstream side is likewise increased.

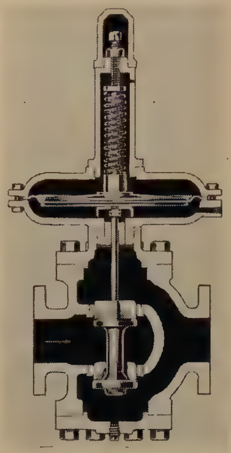

Fig. 103. Cross section of a typical pressure-regulating valve (*Courtesy Fisher Governor Company*)

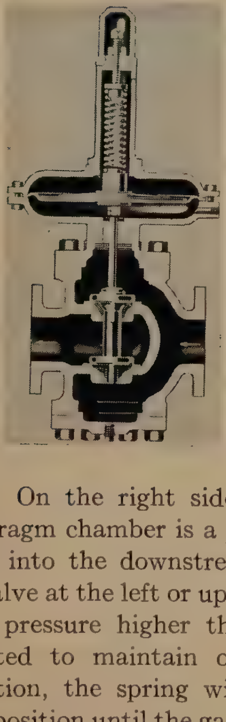

Fig. 104. Cross section of a typical pressure-relief valve (*Courtesy Fisher Governor Company*)

Pressure-relief Valves. It is essential that atmosphere gas converters and Neutralene gas producers be operated above some specified minimum flow which is necessary to maintain proper operating temperature. To assure this condition, an automatic pressure-relief valve is sometimes utilized—for example, where the generator supplies several furnaces, and when the control point of the gas atmosphere flow is at each furnace. Fig. 104 shows a cross-sectional view of a typical relief valve. In comparison with Fig. 103, it will be noted that the construction of the valve is very similar, the main difference being that the operation of the valve is reversed and that when the diaphragm moves upward, the valve opens in the relief valve, whereas it closes in the pressure-regulating valve. It will also be noted that the incoming gas enters at the right instead of the left side of the valve body. Since the drop in pressure through a generating unit varies with the flow, a decrease in the output gas to the furnaces will cause an increase in pressure on the output line. A pressure-relief valve connected into this line can then be adjusted to open when the back pressure reaches a certain point and thus insure that a prescribed minimum flow will be maintained through the generator.

Fig. 105 shows a schematic diagram illustrating the installation of pressure-regulating and pressure-relief valves. In such an installation where the gas is being supplied to bell-type furnaces, the pressure-regulating valve would be set to maintain a pressure of 2 to 3 in. of water in the low-pressure furnace header. Because of the low pressure, the regulating valve would be placed close to the header, and the pressure connection to its diaphragm chamber would be connected from the header, thus permitting the valve to maintain the pres-

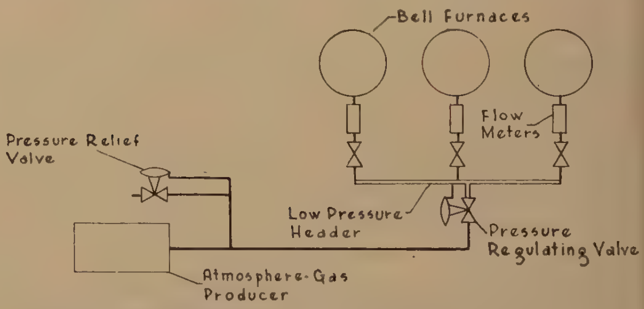

Fig. 105. Schematic diagram of a typical installation of pressure-relief and pressure-regulating valves in conjunction with atmosphere gas converter and bell-type furnaces

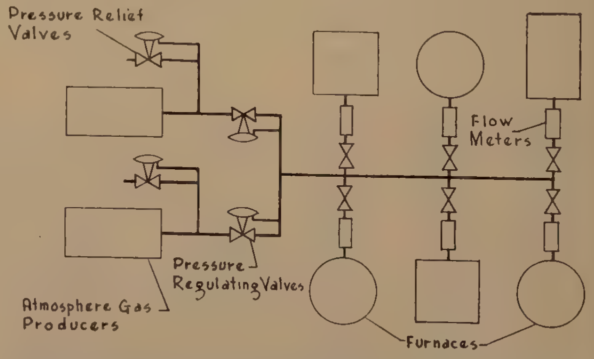

Fig. 106. Schematic diagram illustrating a method of operating atmosphere producers in parallel and distributing the atmosphere to a number of furnaces

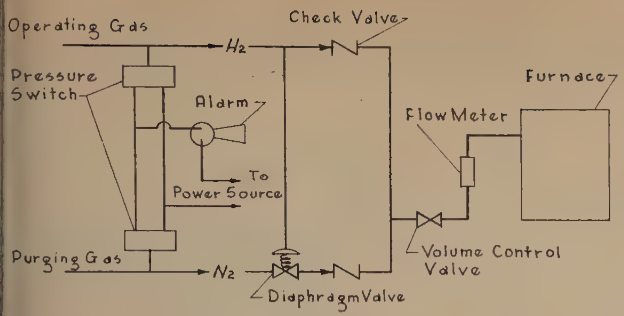

Fig. 107. Schematic diagram showing a pressure-operated valve arranged for automatic changeover from normal to standby-atmosphere supply

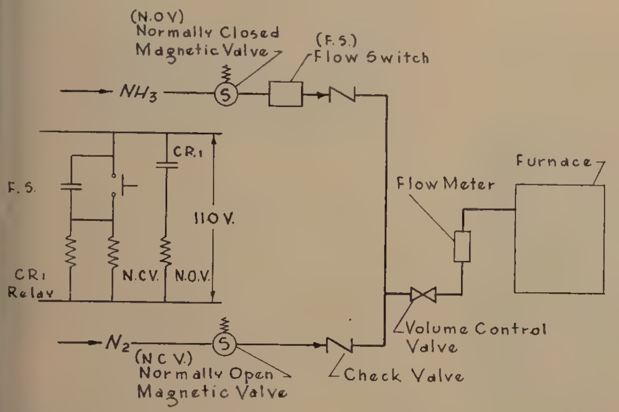

Fig. 108. A method for automatic changeover from normal to standby atmosphere by use of electrically operated solenoid valves

re in the header close to the furnace bases rather an in the pipe line from the producer. Such an arngement allows the atmosphere gas to be delivered om the producer to the regulating valve at a pressure 15 to 20 in. of water which permits the use of a naller size pipe line and gives more latitude in operaon of the producer.

Fig. 106 is a schematic diagram which illustrates a entral type of installation for generating equipment here two or more producers are used in parallel to pply a number of furnaces of different types. By the se of a relief valve and a regulating valve for each roducer, the flow can be automatically equalized beween the two producers. It is suggested in this case at the gas be delivered to the furnace header at ressure of approximately 8 in. of water.

Automatic Switchover to Standby Gas Supply. With me installations, as previously mentioned in this art, it is desirable or necessary to supply a standby or ibstitute atmosphere. In such cases, it is sometimes nportant that the changeover from the normal atosphere supply to the standby supply be done autoatically. One method of effecting this automatic hangeover is by the use of a diaphragm-operated alve as illustrated in Fig. 107. This schematic diagram lustrates a method of automatically purging with itrogen a furnace which normally operates on hydroen gas. A diaphragm-operated valve is located in the itrogen line; this valve would normally be maintained an open position by a spring located on the bottom side of the diaphragm. The top side of the diaphragm chamber is connected to the hydrogen line. In normal operation with hydrogen flowing, the valve is so adjusted that the pressure on the diaphragm from the hydrogen line will overcome the spring pressure and maintain the diaphragm valve in a closed position. Any time that the pressure in the hydrogen line diminishes below the set point or falls off completely, the diaphragm valve will open and admit the nitrogen gas. Check valves are used to prevent any possibility of either gas backing up into the other line. Pressure switches connected in both lines and wired into an alarm system operate a signal to the operator if failure of either gas occurs.

Another method, shown in Fig. 108, is sometimes used which is particularly desirable when the normal operating atmosphere is dissociated ammonia. Since loss of power in the dissociator might cause undissociated ammonia to be carried over, it is desirable to change over to the auxiliary atmosphere by electrical means. This diagram illustrates the use of a normally closed magnetic valve in the dissociated ammonia line and a normally open valve in the nitrogen line. In operation, both valves are energized, the dissociated ammonia valve being held open and the nitrogen valve being held closed. In case of power failure, the nitrogen line is then opened automatically. Utilization of additional protection is shown by the flow switch which will serve to open the nitrogen line if the flow of dissociated ammonia is discontinued or decreased below a set point. An alarm system, of course, can be applied as another precaution.

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(24)"Safe Practices for Liquefied Petroleum Gases," by E. O. Mattocks, *Metal Progress*, Jan. 1949
(25)Partial list of ammonia manufacturers and distributors:
Armour Ammonia Works, 1355 W. 31 St., Chicago, Ill.
The Barrett Division, Allied Chemical & Dye Corp., 40 Rector St., New York, N. Y.
E. I. Du Pont de Nemours & Co., Inc., National Ammonia Div., Philadelphia, Pa.
Mathiesen Chemical Corp., Niagara Falls, N. Y.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

(To be continued)

SEXTON CAN COMPANY
Incorporated
Everett Massachusetts
Manufacturers of
Ash Barrels
Kitchen Waste Cans
Underground Garbage Receivers
CAPACITOR CASES
both Fabricated and Deep Drawn
FIVE GALLON
Open and Closed Top Shipping Containers
METAL STAMPINGS
SPECIAL SHEET METAL WORK

HIGH LIGHTS AND SIDE LIGHTS

Leak Detector Tests New Radiant-heating System

The usefulness of the halogen leak detector in home construction has recently been proved. A leakproof condition was insured in the radiant-heating system being installed in a new house—thereby avoiding the considerable difficulty and expense of later repair of leaking pipes and wrecked plaster—by testing the system with the leak detector.

The pistol-shaped pick-up of the leak detector moves along pipes and over joints of the radiant-heating system. Escape of Freon through a leak is indicated on the panel atop the stepladder

This electronic instrument, which is extremely sensitive to halogens, can detect leaks of these gases from openings so small as to release only one ounce in a century.

To make the test, Freon was first introduced into the 1800 feet of half-inch copper tubing installed in the unfinished ceiling of the house. Then the tip of the instrument's portable pick-up was passed through the air surrounding the tubing. The presence of any trace of the halogen compound was immediately indicated on the dial of the leak detector's electronic unit.

The checking of about a hundred joints in the tubing in this manner in less than two hours spotted three leaks which had been undetected by two previous tests of different types.

Cableways at Work in Construction of French Dam

Two 25-ton tautline cableways, with a span of 1146 feet between towers, being used in construction of France's giant new Chastang Dam. Self-propelled and covering the entire range of the construction, they have carried to all dam-site points machinery, forms and materials, 20-ton sections of high-pressure penstocks, and even a small diesel-electric locomotive. As one of four dams on the Dordogne River, Chastang will rank second in France in power (255,000 kw) and third in output (540,000,000 kwh annually)

Automatic Metal Cutting Guided by Electric Eye

A new electronic instrument has been developed which can follow the lines of a drawing with an electric eye and guide a machine tool to cut out metal parts according to the drawing.

Known as the "contour-following system," the instrument is so connected to a machine tool, such as a jig-borer, that the machine's cutting tool reproduces in metal a drawing "seen" by the electric eye. As the "eye" moves along the lines of the drawing, the position of the cutting
tool is changed accordingly by means
an electronic control system.

The contour-following system has bee
designed to simplify the manufacture
irregularly shaped metal parts which a
difficult to make by hand-controlled m
chining methods. Through the use of th
new device, production of any shape ca
begin as soon as an accurate drawing h
been made.

The contour-following system, whic
can follow a curve as small as that of th
pupil of a human eye, scans the line of
drawing through a low-power microscop
When the line is in the center of th
microscope's field, the electric eye sen
out a signal, at a frequency of 60 cycl
per second, which is picked up by a 2
tube electronic circuit. If the phase of th
signal varies, indicating that the line
not in the center of the field, the circu
instantly sets mechanical guides int
motion to bring the eye and microscop
back into position. The jig-borer's cuttin
tool moves simultaneously. The instru
ment does not vary from the drawn lin
by more than 0.003 inch.

The microscope and electric eye ar
placed on a movable mount, which res
on a lathe bed. The drawing to be repro
duced in steel is set a fraction of an inc
from the microscope on another movab
mount. The microscope and eye mov
in their mounts to follow a line runnin
left or right; when the line travels up
down, the drawing itself changes positio
accordingly. These motions are tran
mitted electrically to the controls on th
jig-borer. The electronic system whic
enables the electric eye to follow a line
located in a separate metal cabinet.

Dual-purpose Locomotives

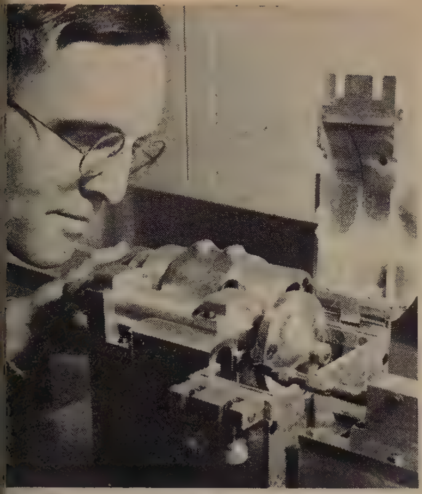
An unusual type of dual-purpose direc
current locomotive has recently be
built for the Chilean State Railway.

For road service the locomotives opera
with power supplied to four tractio
motors directly from the 3000-volt d
overhead line. In this service they have
hourly rating of 1500 metric horsepow
and a continuous rating of 1285 metr
horsepower.

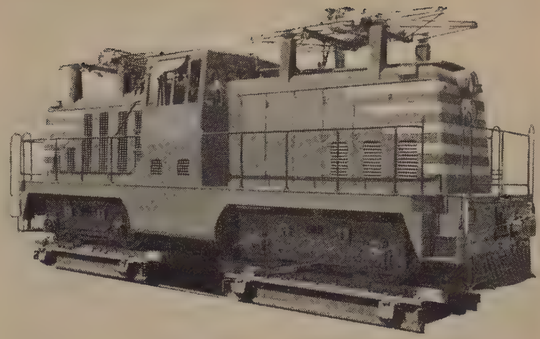
In switching service, the motors opera
at 1500-volt direct-current power su
plied by a dynamotor-generator
which obtains power from the overhe
line.

Each locomotive has two operati
stations and two pantographs; each is
ft long and has a maximum permissib
speed of about 50 miles per hour.

Shock-produced Slices



What is believed to be the thinnest slice ever made by man—a metal shaving less than 0.000002 nch thick—was recently cut by the high-speed microtome, here shown about to slice a portion of a human tooth. Severing of the ultrathin sections is credited to the presence of a shockwave, which forms in the sample before the blade, moving at near-sonic speed, actually reaches any point in the specimen



Combination road and switching locomotive, 77-ton 3000-volt d-c. No. 1 end at right

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Brush-stabilizing Mechanism

A device has been developed which is xpected to more than double the life of brushes and commutators in series-wound eavy-duty motors. Designed for fracional-hp motors used in portable electric ools, the new brush-stabilizing mechaism counteracts the wedging effect of the ommutator and causes the brush to ride reely in the brush holder.

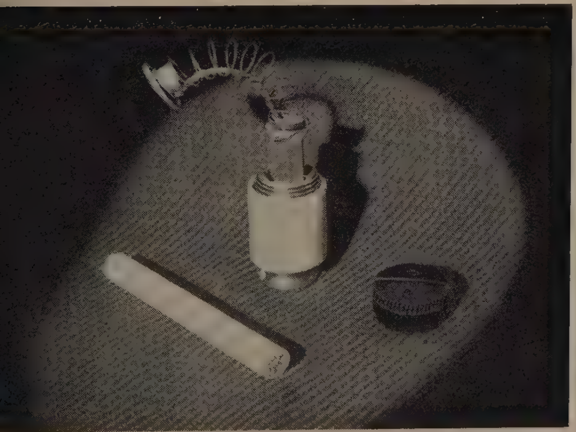
The device makes it possible to retain verload capacity of series-motor parts nd at the same time greatly increase brush life through the elimination of eflected vibration to the brush and the wedging of brush against brush holder by he force of the rotating commutator.

The new mechanism has been designed o interchange with standard mechaisms as outlined in the NEMA standardiation of series-wound motor parts.

The normal cartridge type of brush holder, as used on portable tools, consists of a brush holder, insulating tubing, brush-and-spring assembly, and a brush cap.

The change to a brush-stabilizing mechanism involves the use of an angular brush top and the addition of a bracket to seat on this brush top. The brush-spring pressure is thus partially resolved into a horizontal component which corrects the brush wedging, improving commutation and increasing brush life.

The addition of a roller to the bracket assures close following of the brush on the commutator and longer commutator life.



Brush holder for a ¼- by ½-in. brush, equipped with the new brush-stabilizing mechanism

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New Generator of "Silent Sound"

There is a research instrument now in use which has scrambled eggs and homogenized mercury and water during experiments with high-frequency sound waves.

Called the "ultrasonic generator," the laboratory device produces sound waves pitched above the range of human hearing. The waves are generated by a wafer-shaped quartz crystal, which vibrates when voltage is applied across it.

During experiments, water placed in a chamber above the crystal quickly dissipated into the air as a fine fog, and glass rods thrust into a fluid through which the waves were passing soon became hot enough to burn holes in paper. The inaudible sound can also be made to shatter glass tubes, mix paint, churn butter, and homogenize milk.

The quartz crystal from which high-frequency sound waves are generated is submerged in oil in the translucent plastic case atop the cabinet

The equipment was developed for research which seeks to determine practical applications for ultrasonics, and has many possible applications in experimental work in the biological, industrial, chemical, and physical fields.

Various sizes of quartz crystals can be used to generate sound waves with frequencies ranging up to one-million impulses per second, the frequency dependent upon the size of the crystal used. The crystals are roughly similar in size and shape to a hockey puck. Energy of the waves generated is several hundred watts.

The equipment is contained in a cabinet which resembles a small floor-model radio. Mounted on top of the cabinet is a transparent cylindrical case filled with oil and enclosing the crystal that emits the silent waves. The oil serves to insulate the high-frequency voltage across the quartz and to transmit the sound waves to a test chamber directly above the crystal.

Experiments with ultrasonics are conducted in the test chamber, a small, hollow cylinder with its base immersed in the oil and its top open to the air. Waves from the crystal travel into whatever fluid the chamber may contain.

NEW PRODUCTS: AND WHAT THEIR MAKERS HAVE TO SAY ABOUT THEM

Switch

A new and exceptionally small lever-action switch called the Lev-R switch, that offers many features of the telephone-type switch at relatively low cost. It is especially adaptable for use on all types of low-power switching applications such as television antenna rotors, small electric trains, money meters, communication radio, amplifier and sound systems, automotive and radio test equipment, signal systems, etc.

It requires less than half the space usually necessary for a lever switch. Only one single hole is required for mounting. It is furnished in standard circuits, in both two- and three-position actuators, either type locking or nonlocking. Mounting hardware is nickle-plated brass, and black plastic knob is removable.—*Switchcraft, Inc., 1328 N. Halsted St., Chicago 22, Ill.*

Precision Tachometer

A new electronic pulse counter for measuring very high speeds. This tachometer equipment consists of a high-frequency pulse generator or pick-up, an electronic counting circuit, and two speed-indicating units: one for on-the-spot readings and the other for remote readings.

The first of these pulse counters is now being used in testing the efficiency of steam turbines, measuring speeds in the range of 0 to 17,000 rpm. In this application, a magnetic pulse generator fits on the periphery of a drum which is attached to the shaft of the machine to be tested. The drum is magnetized, one side containing 150 magnetic poles and the other side 1500. When rotated, the drum generates electrical impulses in the magnetic pick-up which are carried to the electronic circuit, and there counted at speeds equivalent to 50,000 cps. The indicators do the necessary calculation and interpolation, and flash on an opal glass screen, in figures approximately 1-in. high, the number of revolutions per minute. Continuous readings are made, and the figures on the screen change every second to indicate any variations in the rpm.—*General Electric Co., Special Products Division, Schenectady 5, N. Y.*

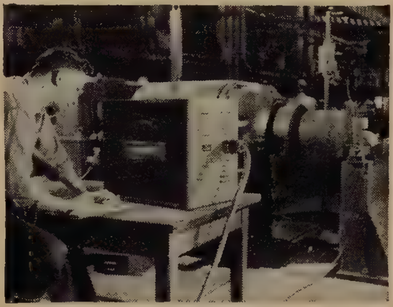
Steam Generators

New steam generators emphasize improvements in basic operating features. A new type of high-atomizing burner nozzle utilizing a primary air supply assures precise injection of fuel and air for efficient combustion at all firing rates. In addition, the nozzle design permits interchangeable oil or gas firing without requiring a change of nozzle. This design combined with the cyclonic-combustion principle maintains high combustion efficiency with either fuel.

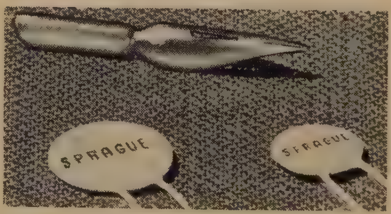
Also included is a simplified air-supply system, improved combustion and ignition programming controls, and a blower-air channel design that achieves quiet operation. This line of generators is available in sizes ranging from 10 to 300 hp, and in pressures from 15 to 200 lb.—*Cyclotherm Corp., Dept. 99R, 90 Broad St., New York 4, N. Y.*

Switch

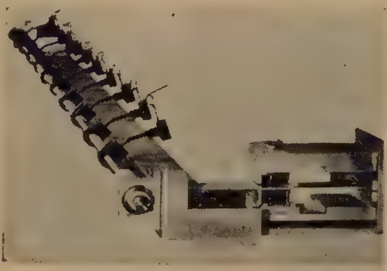
Surface Plate



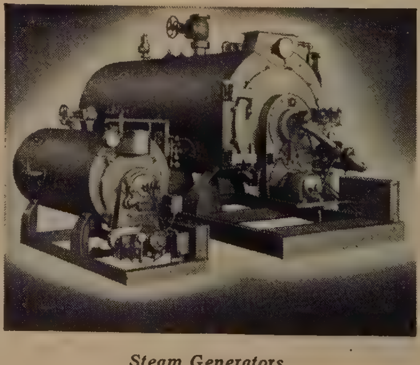
Precision Tachometer



Ceramic Capacitors



Tensiometer



Steam Generators

Surface Plate

A heavy cast-iron surface plate for layi out work, checking flat surfaces, and gener toolroom and shop use. This plate made special quality close-grained iron, having high resistance to wear, is heat-treated prevent distortion. The surface is precisi ground, and all edges are accurately m chined. The bottom is heavily ribbed ar has three-point support.

Toolmaker's V-blocks, supplied in matche pairs only, are also available for use with t surface plate. An additional item for u with the surface plate is the angle plat which is precision ground on 6 sides: serves as a square for laying out and settin up work, and it is suitable for checking ar finishing right-angle surfaces.—*South Ber Lathe Works, 205 East Madison St., Sou Bend 22, Indiana.*

Ceramic Capacitors

Tiny wafer-thin disk ceramic capacito not only save chassis space but reduc assembly time and improve the performan of television and f-m receivers. These capa itors consist of a half-dime or dime-size ceramic plate of high-dielectric constar with silvered electrodes fired on both face of the disk. Unidirectional leads are soldere to the silvering, and the capacitors ar coated with a tough moisture-resistar insulating resin. Such construction assure a neat fit across miniature tube sockets, a well as units that are efficient as high frequency bypass capacitors. These dis capacitors have a high insulation resistanc and they are also useful as coupling capa itors in low-frequency circuits.—*Spragu Electric Company, North Adams, Mass.*

Tensiometer

A new instrument, called a yarn tension eter, for obtaining accurate quantitati data on tension conditions in textile spi ning. The device measures yarn tensio and, by means of a recorder, gives a pe manent visual record of the measuremen It provides an accurate check on the tensi of yarn as it is wound on bobbins, enablin manufacturers to operate under optimu tension conditions and thus produce a fir uniform package of yarn.

The equipment consists of a shaft, whi is bolted to the frame in place of the threa board; an armature strip which is connect to the shaft; two coils or strain gages forn ing a balanced circuit on either side of t armature strip; and a power supply. Rang of sensitivity are readily adjustable b moving the coils closer to or farther fro the armature, or by adjusting the stiffne of the blade itself.—*Special Products Di sion, General Electric Co., Schenectady, N.*

Plastic Cement

Dekadhese, a new plastic cement, f solving tough adhesive problems in scien and industry. Preliminary tests and applic tion in critical scientific problems in mar research laboratories indicate that it w cement many unusual materials together some for the first time.

Because of its absolute lack of color and genuine clarity, a ready use has been found for the cement in applications involving invisibility and extreme clarity, such as the cementing of glass and acrylic and cellulose plastics.

This fast-drying cold-setting cement remains permanently flexible, and does not crystallize or become brittle. Other qualities include its high resistance to oil and gasoline, vermin and mold, and water and moisture vapor; high dielectric strength; and high wet-bond strength.—*Hayes Research Co., 678 Massachusetts Ave., Cambridge 39, Mass.*

Portable Saws

A new line of Silver Line portable electric saws, having long-shaft transverse motor mounting for extra power and longer tool life. Six new types are available in 6-, 7-, 8-, 9-, 10-, and 12-in. sizes. Special features include die-cast aluminum housings, fully reinforced and protected to withstand rough handling; steel inserts for bearings and threads to maintain critical parts in permanent alignment; built-in saw blower, which blows from the inside to keep cutting line clear and motor free from dust; steel rip guide with adjustments for any thickness of material being cut; giant switches, which give positive protection against accidental starting; smooth-operating automatic ball-bearing blade guard with rubber snubber; finger-tip control for depth and bevel cuts; complete ball-bearing construction using larger bearings than in other saws of this type; and convenient handles for better balance and easier handling.—*Independent Pneumatic Tool Co., Aurora, Illinois.*

A-c Load Visualizer

A new and improved a-c load visualizer, Type AF-2, combines five instruments in one. Besides serving as a standard ammeter and a voltmeter, the device can be used with a split-core or conventional instrument transformer to extend the range for determining watts, vars, volt-amperes, and power factor.

The instrument can be applied in load surveys, induction-motor tests, reactive-power studies, and power-factor checks in power and lighting circuits. The unit is self-contained to 50 amp; extensible to 1000 amp by split-core current transformer. This provides a highly desirable hook-on feature, enabling surveys to be made without interrupting service or cutting conductors.—*General Electric Co., Meter and Instrument Divisions, West Lynn, Mass.*

Flexible Abrasive

A new abrasive for cleaning and polishing metals consists of a fine-grain abrasive material held together by a flexible bond and molded in stick form. This product makes regular commutator and slip-ring maintenance easy and insures good results. When held against a turning commutator it removes high-resistance film, dirt, and grease. Because it is nondusting, it does not affect the face of the brush or cause filling of the commutator slots. It can be used while the motor or generator is in operation, since it is nonconductive and nonloading. In production and machine shops, the abrasive removes tool marks, scratches, or rust leaving a highly polished finish on copper, brass, bronze, iron, steel, aluminum, and other metals.—*Ideal Industries, Inc., 1642 Park Ave., Sycamore, Ill.*

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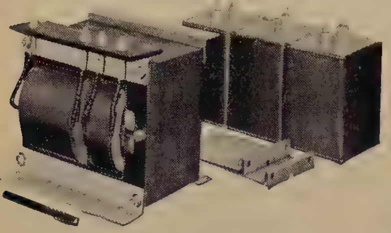
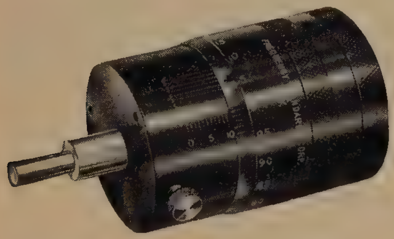
Lamp Ballasts

A new line of stabilized-output ballasts for use with photochemical lamps. These ballasts are designed for manufacturers of blueprinting machines and similar photochemical apparatus which demand close control of lamp light output. They also combine a high-reactance transformer with a capacitor bank for high-power-factor operation of a specific lamp at constant watts, under conditions of varying line voltage. At rated frequency, these stabilized-output units will maintain lamp watts within ±2 percent, even where the line voltage variation is as great as ±13 percent. The ballasts are of core-and-coil construction.—*General Electric Co., Specialty Transformer and Ballast Divisions, Fort Wayne, Indiana.*



Micrometer Head

A new type of precision micrometer head specifically designed for the electronics industry. Of major interest in its design are the size, readability, and the antibacklash screw thread. Size of thimble is 2⅛ in. diam; readability is made positive by use of yellow-colored scales against contrasting black anodized aluminum; and the antibacklash screw thread, which also compensates for thread wear, provides a positive spindle reading in either direction of rotation—an important feature for many electronic uses. Temperature compensation is accomplished by use of both an Invar spindle and nut, the spindle threads being hard chrome and the nut threads silver-plated to provide good wearing surfaces.



The head is available in either English or metric scales with both 1-in. and ½-in. thread travel offered in either scale.—*Frequency Standards Corporation, P.O. Box 66, Eatontown, N. J.*

Cable Jacket

A new anticorrosion jacket applied at the factory to leaded cable of the type used by electric utilities. The corrosion-protective covering is a taped, vulcanized neoprene hose jacket applied in the following manner: The lead sheath is coated with an adhesive, and three glass-fabric tapes, impregnated and coated with a substantial thickness of neoprene, are then applied spirally. This is followed by a wrap of cotton-reinforced neoprene tape, with a 10-percent overlap. The jacket is then vulcanized, after which a smooth wax finish is applied over the completed jacket, the total thickness of which is nominally 0.079 in.

This new protective covering offers many advantages. It allows a substantial reduction in the thickness of the lead sheath, which in turn means that the cable is lighter in weight and smaller in diameter than usual. The use of this neoprene jacket also gives a much longer service life to the cable.—*Construction Materials Dept., General Electric Co., Bridgeport 2, Conn.*

Stainless Steel

An unusual combination of advantages is provided in a new grade of stainless steel called Armco 17-4 PH. This alloy has high hardness and strength, excellent corrosion resistance, good fabrication characteristics, and requires only a low temperature (850 to 1000 F) hardening treatment. It can be used for gears, cams, shafting, chains, valves, and pump parts in equipment where high mechanical properties and corrosion resistance better than can be obtained with present standard hardenable grades are necessary.

Containing chromium, nickel, and copper, this alloy has a corrosion resistance superior to that of the standard hardenable alloys and approaching that of 18-8. Hardness values of Rockwell C40 to 45 are obtained by precipitation hardening.

Since only an easily removed surface discoloration is produced in this process, parts can be finish machined before hardening. This eliminates expensive grinding or finish machining normally required after that treatment.—*Armco Steel Corp., Middletown, Ohio.*

Flow-measuring Instrument

A precision air meter which has two ranges for measurement of air velocities in the range of 0 to 400 and 400 to 6000 fpm. The instrument will measure air velocities as low as 6 fpm. The meter is applicable to the measurement of air velocities in ducts, flow in air and gas lines, surveys of heating and air-conditioning systems, process control and meteorological studies.

Operation of the instrument is based on a combination of the hot-wire and thermopile principles. This arrangement increases accuracy by eliminating errors due to air-temperature variations. The output is suitable for remote indication and operating a standard strip- or circular-chart electrical recording instrument.—*Hastings Instrument Co., Inc., Box 1275, Hampton, Virginia.*

Tubular Insulation

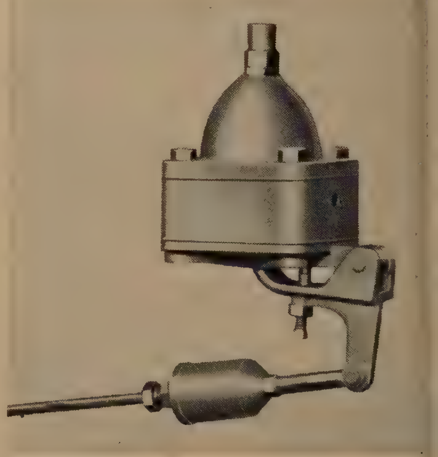
A new braided Fiberglas tubing and sleeving, known as BH 649, with superior physical and dielectric properties. It stands up under rough treatment, such as knotting, twisting, and direct flame, without sign of insulation breakdown. It can be cut cleanly thus making wire threading easy because there are no frayed ends.

This insulation has met severe laboratory heat tests. Potting temperatures of 450 F up to 60 min may be used, or the insulation may be exposed to 220 F for 96 hr with practically no physical change or loss of dielectric strength. The megohms resistance is 50,000 when dry, 10,000 when wet.—*Bentley, Harris Manufacturing Co., Conshohocken, Pa.*

Floating-speed Regulator

A new U1-83 floating-speed regulator simple to operate and easy to adjust for Drill-More capacity control. Speed steps and cycling are eliminated; average air pressures are 15 to 20 psi higher; and savings in fuel are up to 40 percent.

Whenever less than full capacity of the compressor is used, this regulator slows down the compressor to the lowest practical working speed that compresses just enough air to hold the pressure. When the air demand changes again, the speed "floats" up or down to the exact speed required.



Compressor cylinders unload only when the minimum speed delivers more air than needed. After reloading, the compressor continues to operate at low speed unless a greater use of air causes it to speed up. Wasteful idling is eliminated, and wear and tear on all parts is reduced.—*Ingersoll-Rand Co., 11 Broadway, New York 4, N. Y.*

Rural Package Substations

Complete ready-to-install substations designed for use on rural systems and available in any one of four basic arrangements. These package substations are designed and manufactured as a unit. The fabricated steel structure, transformers, switchgear, lightning arresters, all components, necessary hardware, erection diagrams, and drawings are included in each installation.

Ratings range from 300 to 1500 kva, 22,000 to 69,000 volts (incoming), 12,470Y/7,200 or 13,200Y/7,620 volts (outgoing). Building-block design readily permits capacity to be added or removed in easily handled blocks of power. They are shipped in factory-assembled sections as large as shipping and handling facilities permit.—*Apparatus Department, General Electric Co., Schenectady 5, N. Y.*

BOOK REVIEWS

(Available books may be purchased through the GENERAL ELECTRIC REVIEW for domestic delivery; none sent on approval.)

ELASTOMERS AND PLASTOMERS: Vol. III—Testing and Analysis; Tabulation of Properties

Edited by R. Houwink—Elsevier Publishing Co., Inc., New York. 1948. 174 pp. $4.50.

This volume of Elsevier's polymer series deals with the testing of elastomers and plastomers, standardization of methods of testing, methods for complete chemical analysis, and summary charts of the properties of the polymers. Each topic is handled by an accepted authority in the field.

The chapter on Methods of Testing describes the tests used today and emphasizes the factors which influence the test results. A real attempt is made to explain the practical significance of the results obtained by these test methods. The author's approach to the subject—namely, that while only a start has been made to date, progress indicates that a *good* start has been made—is essentially sound and worthy of keeping in mind at all times.

The treatment of chemical analysis of polymers deals with methods of identification and methods of complete chemical analysis of practically all polymers after identification. The subject is handled in a masterful manner and the procedures appear technically sound.

The tables of properties of both the elastomers and plastomers are complete with respect to properties and materials handled. The listing of some properties in both the cgs system and the Anglo-American system is helpful and time-saving.

In conclusion it may be stated that the subjects are well presented and well documented and the book should be of interest to those working in the field of plastomers and elastomers.

J. J. PYLE

PATENT LAW (Second Edition)

Chester H. Biesterfeld—John Wiley & Sons, Inc., New York. 1949. viii + 267 pp. $4.00.

Extensive revisions have made the present edition of this book a great improvement over the first, which it was this writer's privilege to review for the GENERAL ELECTRIC REVIEW.

Mr. Biesterfeld, being the head of the Patent Department of the Du Pont Company, has had extensive experience in the practice of patent law and draws upon such experience in setting forth clearly and concisely the problems involved in obtaining and maintaining patent rights. He has the faculty for reducing technical subjects to readily understood language.

The author handles in an especially erudite fashion the problems peculiar to patent claims which define the scope of the patentee's domain. His treatment of the difficult subject of what constitutes patentable invention is quite comprehensive.

It is regrettable that shortly after the author completed this revision of the first edition of his book, the United States Patent Office revised its Rules of Practice by renumbering them and modifying many of the provisions of the rules, especially those rules relating to appellate and interference procedures. That fact, however, need not deter persons from reading and owning this book, because it is one of the more palatable attempts to interpret the law of patents for persons both unversed and versed in the subjects. Patent attorneys will find the book a ready source of decisions interpreting many intricate questions of patent law.

JOSEPH T. COHEN

ELEMENTS OF MECHANICAL VIBRATION (Second Edition)

C. R. Freberg and Emory N. Kemler—John Wiley & Sons, Inc., New York. 1949. xiii + 227 pp. $3.75.

In every branch of engineering, vibrations are present. Some vibrations are objectionable, because they cause noise, excessive wear, or failure of parts. Others are desirable, because they are pleasing to the ear or perform some useful function.

Whatever the application, it is necessary to understand these vibrations in order to

(Concluded on next right-hand page)

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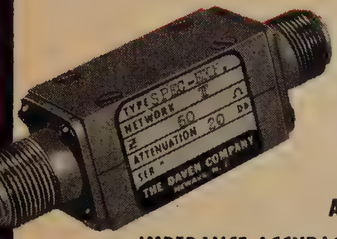


CIRCUIT: π network.
IMPEDANCE: 50 ohms.
LOSS: 5 to 20 DB.
ACCURACY: ± 2% at D.C.
IMPEDANCE ACCURACY: Same as series RF-540

R. F. VARIABLE ATTENUATORS

SERIES RF-540

CIRCUIT: π network.
IMPEDANCE: 50 ohms.
NO. OF STEPS: 4 (push-buttons.)
RESISTOR ACCURACY: ± 2% at D.C.
IMPEDANCE ACCURACY: Terminal impedance of loss network essentially flat from 0-225 MC.

LOSS:
Type RF-540—1, 2, 3, 4 DB (10 DB total.)
Type RF-541—10, 20, 20, 20 DB (70 DB total.)
Type RF-542—2, 4, 6, 8 DB (20 DB total.)
Type RF-543—20, 20, 20, 20 DB (80 DB total.)

SUGGESTED APPLICATIONS

- In signal generators.
- In field strength measuring equipment.
- Nucleonic and atomic research.
- Television receiver testing.
- Wide-band amplifiers.
- Pulse amplifiers.
- Any application where attenuation of UHF is required.

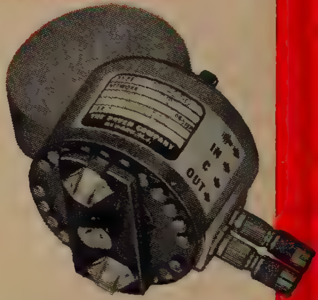
VIDEO FIXED ATTENUATORS

TYPE V-154

CIRCUIT: "T" network or equivalent.
IMPEDANCE: 75 ohms.
LOSS: 1 to 20 DB.
ACCURACY: ± 1% at D.C.
FREQUENCY CHARACTERISTICS: Essentially flat to 10 MC.

VIDEO VARIABLE ATTENUATORS

SERIES V-250



CIRCUIT: "T" network.
IMPEDANCE: 75 ohms.
RESISTOR ACCURACY: ± 1% at D.C.
FREQUENCY CHARACTERISTICS: Essentially flat to 10 MC.

TYPE	NO. OF STEPS	DB PER STEP	TOTAL DB
V-250	10	1	10
V-251	10	2	20
V-252	20	1	20
V-253	20	2	40

These units will be supplied with co-axial connectors or regular terminal boards with lugs.

NOTE: *A video push-button control, similar to the R.F. push-button unit shown, is available.* ***Additional information will be furnished on request.***

SUGGESTED APPLICATIONS

- In television video circuits where a wide frequency range without change of impedance is of special importance.
- Wide-band amplifiers.
- Pulse amplifiers.

Patent applied for.

THE DAVEN CO.
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BOOK REVIEWS (Continued)

eliminate or produce them. This book treats vibrations from the fundamental concepts. The more elementary phases of vibration are considered and placed in such form that they can be readily applied to practical problems. An extremely wide range of these problems is treated, and accompanying each one is a clear, adequate explanation. Closely associated with vibration is sound, and a short, comprehensive chapter has been added to the book, presenting the practical aspects of sound and a few of the fundamentals of acoustics.

A novel feature is a detailed and clear-cut explanation of the mobility method for handling vibrations. This method eliminates the use of differential equations, making it a boon to one who is a bit rusty.

The authors have succeeded in producing an excellent book for beginners in the study of vibrations.

H. C. Ward

Rocket Propulsion Elements

George P. Sutton—John Wiley & Sons, Inc., New York. 1949. ix + 294 pp. $4.50.

To anyone new in the engineering of rockets, or to those who want to re-examine the fundamentals of modern rocketry, this book is an excellent introduction. Beginning with a definition of terms used in that branch of engineering and a short history of rocketry, the basic thermodynamic relations and performance criteria are developed and applied to typical design problems.

The middle third of the book deals exclusively with liquid rockets. This emphasis is not unfounded, since the great bulk of modern rockets—past, present, and on the drawing boards—are of the liquid type. After a thorough but lucid discussion of propellant performance, the physical and chemical properties of various liquid propellants are described. These sections will be well appreciated by engineers who have not had much chemical training. Considerations of liquid-rocket motor design are followed by typical sample calculations. A chapter on liquid-propellant feed systems includes a close examination of the V-2 power plant.

The closing chapters deal with the calculation of flight performance, together with a comparison of rockets, ramjets, turbojets, and propeller-drive aircraft. Rocket testing and solid-propellant rockets are given brief but, for this type of book, adequate coverage.

The many excellent illustrations and the author's actual experience add to making this book a good basic rocket-design manual.

Robert V. Klint

Electric and Diesel-electric Locomotives

D. W. and M. Hinde—The Macmillan Co., New York and London. 1948. 376 pp. $9.25.

Since railroad motive power in the United States seems to be well on the way toward electrification in one way or another, *Electric and Diesel-electric Locomotives* should be received with considerable interest by those interested in modern railroad motive power.

The book is almost exclusively descriptive of electric and diesel-electric motive power and omits entirely data pertaining to their application and economics. A chapter on economics and applications, a more comprehensive treatment of why electric drive is used so extensively with the self-propelled units, and brief descriptions of the speed-tractive effort characteristics of the several types studied would add materially to the usefulness of the volume.

The relative rapidity with which the diesel-electric is finding acceptance and the consequent rapid development of new models, refinements to control systems and equipment, coupled with the fact that the past two years have witnessed the construction of some notable electric locomotives in the United States and abroad make difficult the task of bringing out a strictly up-to-date text on the subject selected.

One of the outstanding features of the present volume is the comprehensive tabulation of 90 pages giving detailed data on the principal designs of both types of locomotives (and two steam turbine-electric machines) produced throughout the world in the period 1925–1947.

T. F. Perkinson

Standard Handbook for Electrical Engineers (Eighth Edition)

Archer E. Knowlton, Editor-in-chief—McGraw-Hill Book Co., Inc., New York. 1949. xi + 2311 pp. $12.00.

With the passing of years, this Handbook has become an institution of generous and familiar feature, to which engineers turn almost instinctively for aid. This new edition becomes available rather promptly to serve in the period of readjustment and transition that follows a war. Many of the new products, materials, and techniques that have come into use within the past ten years or so will find a permanent usefulness, and hence must inescapably become handbook material. In the present volume, such matters have received attention in the text. New pages have been included to keep abreast of developments in electronics, servomechanisms, airplane power systems, nuclear research, magnetic materials, conductors, and insulations.

Specifically, text material pertaining to radar, loran, and other new microwave techniques has been added; carrier-current communication, relaying, and telemetering text has been amplified; likewise, the material on high-voltage generators includes new developments such as the betatron. A new chapter on nuclear energy and radioactivity takes its place with the earlier treatises on ultraviolet energy and x rays in the section on electrophysics, which concludes the text.

The section including industry codes and standards has been modified drastically. Possibly in deference to the modern penchant for designations by initial, a listing of initials used to identify engineering societies, industrial associations, and government bureaus is included; this, together with a skeletonized guide, is substituted for the extensive specific listing of published standards that appeared in the seventh edition.

In general, the handbook is a counterpart of its predecessor in content, arrangement, and dimension. There has been a slight rearrangement of tabulations, which are now usually designated by Table numbers. The bibliographic material has been revised, and many new references are included. A new numbering system for illustrations and equations keys the individual item with its particular section.

The apt little proverb that introduces the Handbook's index might well be paraphrased into a tribute to the experts who compiled it, for this index has been abundantly amplified through the concentrated attention of the editors: "An expert is largely a man who knows where and how to find the answers." And this, in a sense, is the complete argument for a good handbook.

J. E. Glick

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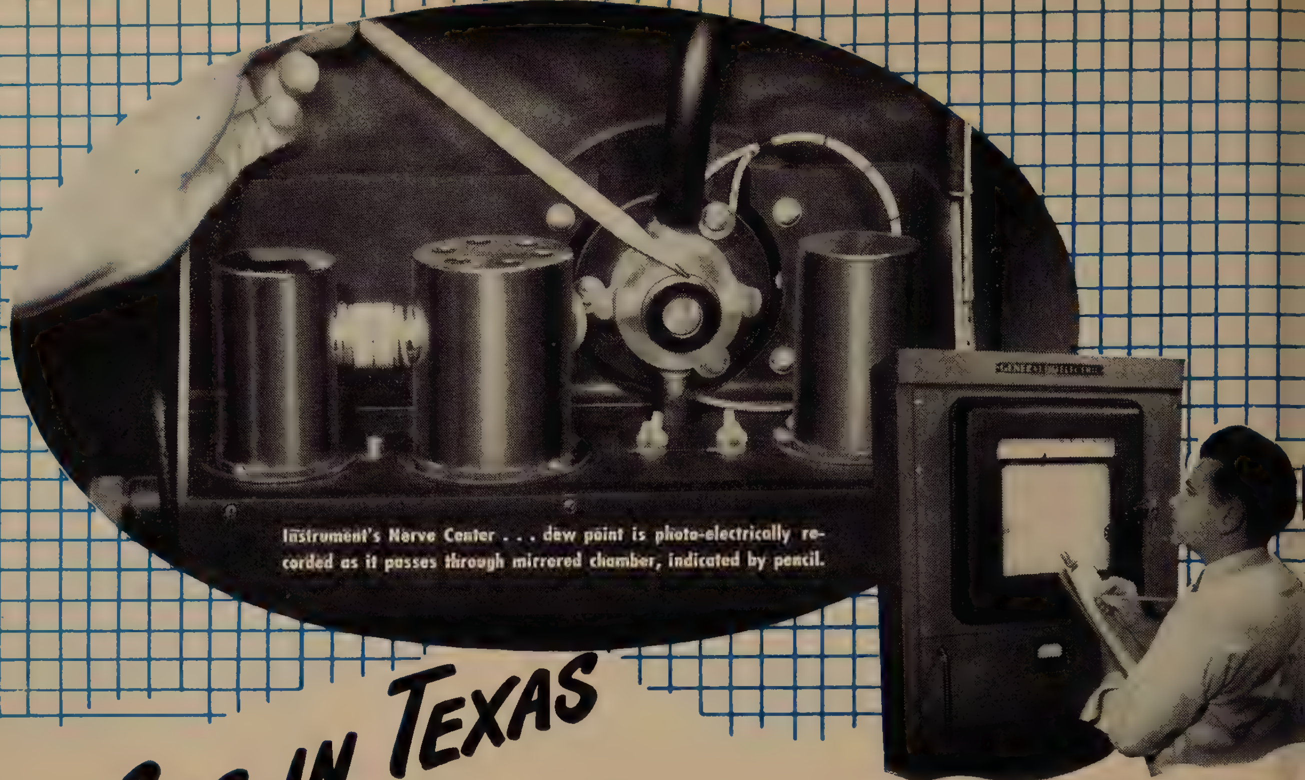

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Gave Industry a New Testing Machine

Natural gas, produced in Texas, and piped to the mile-high city of Denver, carries some water vapor. As in all gases, if the vapor is excessive, a reduction of volume or temperature causes the vapor to condense into water. Lowering temperature at high pressure causes the formation of hydrates or pipeline ice, which shuts off the flow of gas, and interrupts service.

This was the problem faced by the Colorado Interstate Gas Company. To prevent winter freeze-ups required controlling the water content in the gas in relation to temperature and pressure. This demanded an equipment that would give an accurate and continuous recording of the water content as the gas passed through the pipes.

Engineers from Interstate Gas and General Electric put their heads together. By employing a photoelectric tube to replace the human eye and get "the desired continuous recording," they conceived and constructed a dew-point recorder.

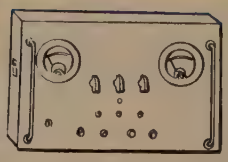
Realizing the importance of this instrument to industry, General Electric engineers made further studies and developments. The result was an improved dew-point recorder.

It gave industry an instrument that determines quickly and records continuously moisture content of gases! An instrument from which the possibility of human error has been eliminated. Dew-point temperature measurements now can be made with an accuracy of better than five degrees at minus 90 degrees F, or two degrees above 20 degrees F.

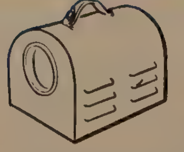
General Electric engineers have helped solve thousands of problems for industry. Frequently, the result has been a new testing and measuring equipment. Equipment that today is saving time and money for industry!

Your problem may justify a development program to create a new product, particularly if it is common to industry. Or, maybe, our engineers can recommend an instrument from the many testing and measuring equipments already available . . . proved equipments that are doing similar jobs. Write us about your problem. Maybe we can help you. *Apparatus Dept., General Electric Company, Section 800-41, Schenectady, N. Y.*

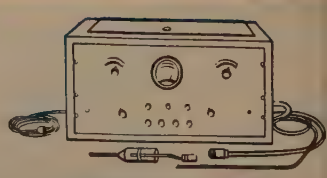
General Electric measuring and testing equipments for nearly every industrial process



Chemical Analysis Equipment



Color, Light and Spectro Equipment

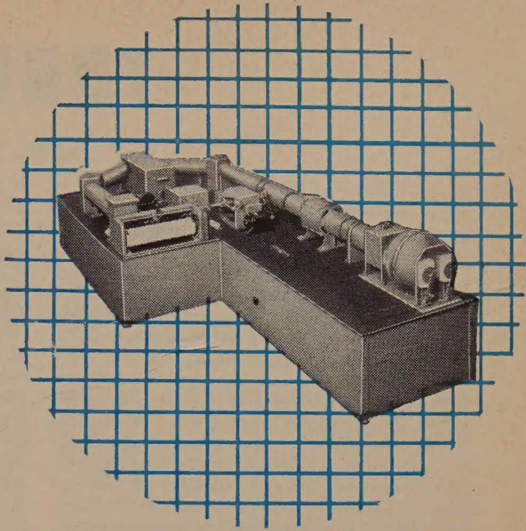


Vacuum and Pressure Measuring Equipment

COLOR . . . Spectrophotometer pays for itself in one project

Ten years ago, the Harshaw Chemical Company developed a new opacifier, called Uverite, to replace tin oxide. A G-E recording spectrophotometer more than paid for itself on this first project. But the important news is this: Harshaw's chemists say it has been paying for itself repeatedly since then by giving quick results and a permanent record for color analysis, comparison, etc.

Many other users are finding this high-precision laboratory instrument valuable for such jobs as matching colors, mixing pigments, making color analysis, measuring gloss, standardizing colors, preparing color specifications, etc. It has been adopted by the American Standards Association as the basic color-measuring instrument. Write for GEA-3680.

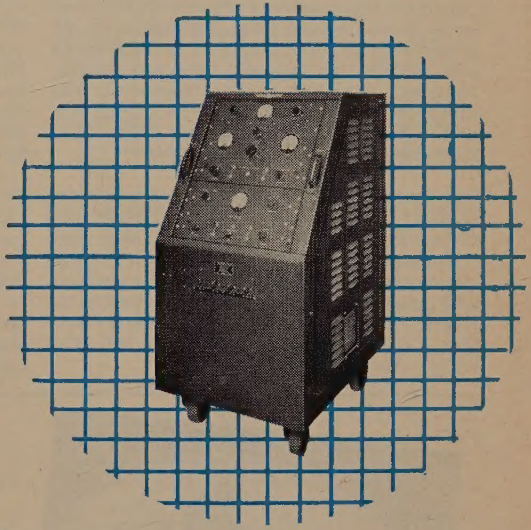


VACUUMS and PRESSURES... Leak detector pays for itself the first month

For testing high-frequency vacuum tubes for leaks, a well-known laboratory installed a G-E leak detector. Previous methods were slow, inconsistent, and inaccurate.

The leak detector proved itself quickly. It made it possible to find leaks many times smaller and much faster, recheck suspected leaks quickly, and assured vacuum tightness of the tubes.

General Electric has leak detectors available for either vacuum or pressure systems . . . detectors sensitive enough to find a leak so small that a quart of air would require 15,000 years to pass through it. Write for GEA-4640 and GEC-233.



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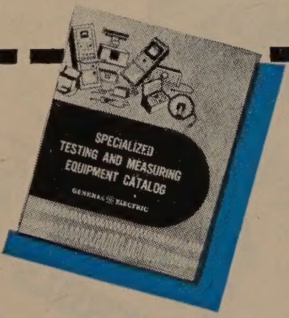

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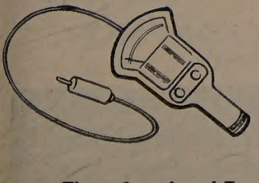
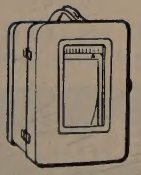
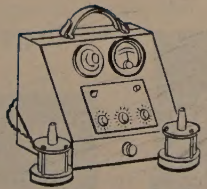


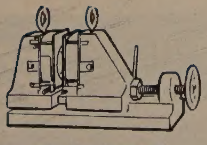
Time, Speed and Torque Equipment



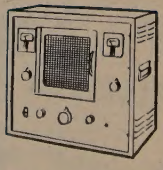
Electric Circuit Testing Equipment



Materials Testing Equipment



Magnetic Equipment



Resistance and Insulation Testing Equipment

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TRADE LITERATURE

Alloy Chain—Complete specifications are given on sizes ¼-in. to 1¾-in. diam; working load limits, definitions and cautions, recommended use, and details of chain service for Taylor Made alloy steel chains, sling chains, and attachments. Well-organized pages of tabular data quickly provide answers to questions. Twelve pages.—*S. G. Taylor Chain Co., Hammond, Ind.*

Cable—Brief descriptions, together with prices, are given for a complete line of soft-temper semiflexible coaxial or solid dielectric cables, rigid coaxial transmission lines with solder or flanged fittings, gas equipment, antennas, and components. Twenty-one pages. Bulletin 10B.—*Andrew Corp., 363 East 75th St., Chicago 19, Ill.*

Electronic Components—An important feature is the summary price sheet which in table form presents the highlights of the entire catalog. The material is subdivided into sections on terminal lugs and boards, swagers, coils and chokes, hardware, and insulated units. Seventy pages. Catalog No. 300.—*Cambridge Thermionic Corp., 445 Concord Ave., Cambridge 38, Mass.*

Insulating Materials—A publication describing Fiberglas and Fiberglas base materials for insulating wire, cable, and electrical equipment of all types. Photographs, charts, and tables cover types of materials and properties. Thirty-six pages; Sources of Supply. Four pages.—*Owens-Corning Fiberglas Corp., Textile Products Div., 16 East 56 St., New York 22, N. Y.*

Metal Framing—Contains pictures, data, and detailed information on how to frame, hang, support and mount various equipment by the Unistrut way. Centerspread of application photographs. Twenty-four pages. Catalog No. 500.—*Unistrut Products Co., 1013 W. Washington Blvd., Chicago 7, Ill.*

Motor Control—A simplified guide to the selection and application of commonly used types of a-c motor control. Lists standard controls and describes operation; discusses the use of magnetic and manual control; and shows when reduced-voltage starting is necessary. Sixteen pages. GEA-4015E.—*Apparatus Dept., General Electric Co., Schenectady 5, N. Y.*

Mounting Material—A description of Elasto-Rib, a low-cost cork-and-rubber mounting that requires no bolting or cementing for the majority of applications, used for control transmission of vibration and noise. Methods of installation are described and illustrated, and likewise three types of damper. Four pages. Catalog ER-701.—*Karfund Co., Inc., 48-21-K Thirty-second Place, Long Island City 1, N. Y.*

Oil Fuse Cutouts—For both indoor and outdoor service. Information concerning basic advantages, exclusive features, prices and data, dimensions, kva ratings, and gang-operating mechanisms represent but a few of the many pertinent facts presented on these various types of oil fuse cutouts. Forty pages. GEA-732K.—*Apparatus Dept., General Electric Co., Schenectady 5, N. Y.*

Oilers—A presentation of the latest line of visual oilers; includes gravity- and wick-feed, constant-level, vibrating-rod, and multiple oilers. Complete specifications are given for each oiler. Eight pages.—*Gits Bros. Mfg. Co., 1846-66 So. Kilbourn Ave., Chicago 23, Ill.*

Timers—Details are given on Minitmaster timers offered in 11 models to meet the various requirements of ranges, washers, refrigerators, and similar appliances. Four pages.—*Telechron Inc., Ashland, Mass.*

Valves and Controllers—Seven bulletins under this general subject are offered, but specific types are treated individually in each catalog. Details of special construction features, typical applications, and determination of valve sizes are given together with schematic drawings, photographs, flow and capacity charts, and dimension tables. The bulletins are: "Hi-Lift V-Port Indicating Type Hand Control Valves," twenty pages, Bulletin No. 242-1; "Series 700 Diaphragm Control Valves," thirty-two pages, Bulletin 700-1; "Regulating Valves for Water, Steam, Air, Gas, or Oil," twenty-four pages, Bulletin No. 10-1; "Liquid Level Controllers," thirty-two pages, Bulletin No. 48-1; "Pilot Single Seat Fully Balanced Regulating Valves," twenty-four pages, Bulletin No. 47-1 "Schaefer By-pass," four pages, Bulletin No. 254-1; "On-Off Air-operated Diaphragm Control Valve," four pages, Bulletin No. 350-1.—*Belfield Valve Division, Minneapolis-Honeywell Regulator Co., Philadelphia 44, Pa.*

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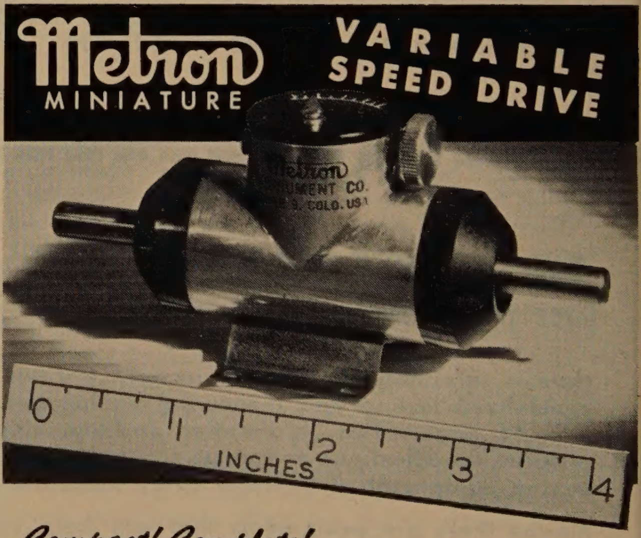

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LIBRARY NOTES

ON ARTICLES IN OTHER TECHNICAL JOURNALS

ADHESIVES

Nature of Adhesion. *Nat. Bur. Stds. Tech. News Bul.*, June 1949; v. 33, pp. 67-69.

Summarizes the results of tests on various kinds of adhesives.

Shear Impact and Shear Tensile Properties of Adhesives, by Irving Silver. *Modern Plastics*, May 1949; v. 26, pp. 95-97, 136-138.

Describes test methods and results applying to resinous adhesives.

AIR CONDITIONING

Anticorrosion Measures Necessary in Air-conditioning Systems, by Joseph I. Montel. *Refrig. Engng.*, Apr. 1949; v. 57, pp. 346-347, 384.

A series of tests on metal samples, indicating the value of continuous chemical treatment for open recirculating water systems.

Automatic Dehumidification of Vented Enclosures, by Max F. Mueller. *Heat & Vent.*, Apr. 1949; v. 46, pp. 73-76.

Describes the use of the sun's heat to reactivate silica gel through which the air of an enclosure is forced by natural expansion and contraction—the principle behind the Solar Radiation Breather, a device developed for Army Ordnance to preserve materiel.

COAL

Liquid Fuel from Coal, by Merritt L. Kastens and others. *Ind. & Engng. Chem.*, May 1949; v. 41, pp. 870-885.

A staff-industry collaborative report.

COAL MINING MACHINERY

Continuous Miner, by Richard K. Lotz. *Mach. Design*, May 1949; v. 21, pp. 88-94.

Illustrated description of the Joy Continuous Miner, a machine for cutting coal from the seam face by means of carbide-tipped bits mounted on electrically driven chains. The machine also conveys the coal to the mine car.

COMPRESSED AIR

Six Ways to Step Up Efficiency of Compressed-air Systems, by Wm. H. Wheeler. *Factory Man. & Maint.*, May 1949; v. 107, pp. 122-124.

Efficiency of operation of compressed-air systems depends on several factors. What these factors are and how they foster economy is explained here.

ELECTRIC CONTROL SYSTEMS

Some Machine-tool Control Circuits, by L. Hesse. *Elec. Mfg.*, May 1949; v. 43, pp. 110-115.

Three examples demonstrating the effective combination of air and hydraulic circuits with electric controls to simplify mechanical design, reduce maintenance, and increase the flexibility of functions.

Controlling Machines with Electronic Counters, by Earl B. Hitchcock. *Mach. Design*, May 1949; v. 21, pp. 112-117.

Description of the use of the decade counter.

ELECTRIC DRIVE

Motors for High-inertia Loads, by Henry Oman. *Power*, May 1949; v. 93, pp. 118-119.

A summary of salient points to consider in addition to the method of computing the load's moment of inertia.

Electrical Controls in Thread-grinder Design, by E. V. Flanders. *Mech. Engng.*, May 1949; v. 71, pp. 381-388.

Electrical methods, as a substitute for mechanical or hydraulic means, for the control of movements in thread-grinding machines.

ELECTRIC LIGHTING

New Approach to Room Lighting, by Parry Moon. *Illum. Engng.*, Apr. 1949; v. 44, pp. 221-225.

To achieve an ideal luminous environment, it is considered necessary for the illuminating engineer to be able to predict whether the design will be satisfactory visually and psychologically.

Fluorescent Lighting Costs, by R. G. Slauer. *Elec. Wld.*, Apr. 23, 1949; v. 131, pp. 96-98.

Diversity of types and sizes of fluorescent sources prevents generalized conclusions on costs. At the moment, however, according to this article, the 40-w T-12 lamp seems to have the edge.

Lighting Cost Comparisons, by R. G. Slauer. *Elec. Wld.*, Apr. 9, 1949; v. 131, pp. 91-93.

For lighting of large areas it is here accepted that fluorescent will cost less than incandescent lighting, although rigorous cost comparison is admitted to be difficult and not necessarily determining even in a specific case.

ELECTRIC MACHINES

Loss-reduction Practices on Electric Power Systems. *Elec. Lt. & Pr.*, May 1949; v. 27, pp. 66-67, 146-148.

A study of the magnitude and distribution of electric power system losses in the U. S.

Vaporization Cooling of Electric Machines, by T. de Koning. *Elec. Engng.*, May 1949; v. 68, pp. 385-392.

Describes the fundamentals of vaporization cooling, the electric machines with this cooling, and the effect of the coolant upon the insulation and other interior parts.

ELECTROMAGNETIC THEORY

Electromagnetic Induction, by George I. Cohn. *Elec. Engng.*, May 1949; v. 68, pp. 441-447.

Attempts to dispel the confusion surrounding the subject.

HELICAL GEARS

Helical Gears to Replace Spur Gears, by Carl A. Johnson. *Mach. Design*, May 1949; v. 21, pp. 149-153.

The accompanying tables list the total number of teeth and the helix angle for a pair of helical gears to replace a pair of spur gears of the same pitch and any total number of teeth from 30 to 107.

MACHINE SHOPS

Indexing Fixtures and Automatic Cycling Cut Production Costs on Dynaflow Parts, by Herbert Chase. *Steel*, May 9, 1949; v. 124, pp. 98-101.

How tool engineers at Buick, foreseeing increasing adoption of torque converters, equipped a new plant to handle the current volume efficiently, with ability to deal with heavier demands in the future.

MACHINE TOOLS

Cutting the Costs of Cutting Tools, by D. G. Baird. *Mill & Factory*, May 1949; v. 44, pp. 112-115.

Some spectacular results in cost data, obtained from comparative tool tests by the Tool Research Department of Ford Motor Company.

When and How to Use Carbide-insert Cutting Tools, by J. S. Gillespie. *Iron Age*, May 12, 1949; v. 163, pp. 84-89.

How tools and toolholders should be designed, applied, and maintained, with particular emphasis on the holder design and the grinding of the inserts.

MEASURING INSTRUMENTS

Pulse Height Distribution Analyzer, by William E. Glenn, Jr. *Nucleonics*, June 1949; v. 4, pp. 50-61.

Description of a device which makes it possible to plot alpha-particle energy against the number of particles emitted of that energy.

Review of Methods for Coating-thickness Determination, by R. S. Bennett. *Jour. Sci. Instr.*, June 1949; v. 26, pp. 209-216.

In particular, two instruments which have been recently developed for use in the plating industry are described, and results are compared.

METAL CLEANING

Chemical Surface Treatments for Metals, by A. E. Durkin. *Tool Engr.*, Apr. 1949; v. 22, pp. 22-25.

Explains methods of cleaning and subsequent finishing of metals.

Liquid Blasting Cleans and Finishes Metallic and Nonmetallic Surfaces, by B. H. Marks. *Mat. & Methods*, Apr. 1949; v. 29, pp. 64-67.

Surface blasting with a high-velocity stream of abrasive particles suspended in liquid, providing an economical means of deburring, descaling, and preparing surfaces for finishes.

METAL FINISHING

Finishing Control, by John A. Zeindler. *Foundry*, May 1949; v. 77, pp. 123, 248-250.

How one company employed more efficient methods to eliminate a bottleneck in its finishing department. Emphasis on methods of finishing castings.

(Concluded on next page)

LIBRARY NOTES (Continued)

How to Finish Machines, by R. E. Gwyther and E. S. Stout. *Am. Mach.*, May 5, 1949; v. 93, pp. 90-93.

Paint is described as more than a beauty treatment when proper original and maintenance finishing pay real dividends in lasting protection.

Finishing of Metal Parts Speeded Up by Electrocoating. *Prod. Engng. & Man.*, May 1949; v. 23, pp. 57-59.

Description of this conveyorized installation for the utilization of electrostatic spraying for finishing metal parts and how it has returned large savings in both labor and material costs.

PROPELLERS, AVIATION

Propeller Flutter, by M. J. Turner and James B. Duke. *Jour. Aero. Sci.*, June 1949; v. 16, pp. 323-336.

A procedure is presented for the analysis of classical subsonic, torsion-bending flutter of propellers, extending the earlier work by Loring for nonrotating airfoils.

REFRIGERATORS

Refrigerator Finishes, by R. N. Sanger. *Refrig. Engng.*, May 1949; v. 57, pp. 460-463, 505-506.

Although great strides have been made in 20 years, new products and improved methods of application are reported in the offing.

STEEL

Rotary Heat-treating Method, by Walter H. Holcroft and Edward C. Bayer. *Steel*, May 2, 1949; v. 124, pp. 87-88, 137.

Described as reducing floor-space requirements and providing greater operating flexibility.

SUPERSONIC SPEEDS

Interferometric Study of Supersonic Channel Flow, by Daniel Bershader. *Rev. of Sci. Instr.*, Apr. 1949; v. 20, pp. 260-275.

Application of the Zehnder-Mach interferometer to the study of supersonic flow of air expanding from a pressure tank into the atmosphere through channels of rectangular cross section.

On Supersonic Flow Patterns, by M. M. Munk. *Jour. App. Physics*, Apr. 1949; v. 20, pp. 302-305.

Deals with the streamline pattern and Mach-line pattern of perfect gases executing a steady plane two-dimensional potential flow.

TELEMETERS AND TELEMETRY

Remote Actuation of High-pressure Valves, by P. R. Weber and J. C. Corby, Jr. *Mech. Engng.*, May 1949; v. 71, pp. 395-396.

Description of an electrical mechanism developed for remote-control purposes.

VALVES

Flow Research Yields New Data on Valve Pressure-drop Characteristics. *Power*, May 1949; v. 93, pp. 106-107, 110.

How the use of air at commercial pressures for test fluid makes experimental work on large valves practical. The setup used to determine pressure drops of existing designs and to study flow behavior of various internal contours for new constructions.

VISCOSITY

The Second Viscosity of Liquids, by L. N. Liebermann. *Phys. Rev.*, May 1, 1949; v. 75, pp. 1415-1422.

Considered here as a measure of the viscous forces which arise when a volume of fluid is compressed or dilated without change in shape.

WELDING

Investigation of Welded Ship Construction, by J. Lyell Wilson. *Weld. Jour.*, Apr. 1949; v. 28, pp. 319-329.

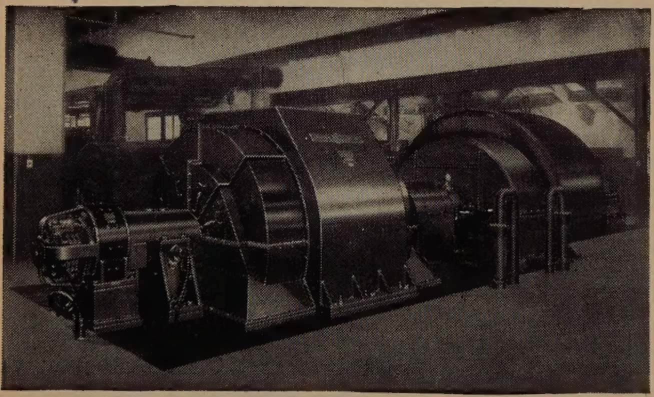
Briefly evaluates some of the more important pieces of research from the point of view of the shipbuilder, under the headings of design, fabrication, and materials.

New Maintenance System Trims Welder Downtime 80 Percent, by William J. Scanlon. *Factory Man. & Maint.*, May 1949; v. 107, pp. 106-108.

Three-step program providing for continuous preventive maintenance of portable and stationary welding machines with the minimum of downtime.

Ultrasonic Weld Inspection, by John C. Smack. *Weld. Engr.*, May 1949; v. 34, pp. 17-20.

Recent improvements adapt the reflectoscope to weld inspection. Ultrasonic vibrations are projected through the plate at an angle by successive reflections and returned when a defect is encountered.



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